INTRODUCTORY BOOK

OF THE

SCIENCES,

ADAPTED FOR

THE USE OF SCHOOLS AND PRIVATE STUDENTS.

In Two Parts.

PART I.—PHYSICAL SCIENCES.

PART II.—NATURAL SCIENCES.

BY JAMES NICOL.

ILLUSTRATED BY ONE HUNDRED AND FIVE ENGRAVINGS ON WOOD.

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PREFACE.

The utility and importance of Physical and Natural Science as branches of general education are now almost universally recognised. Some acquaintance with their more general laws and common facts is admitted to be not only useful, but even necessary, to persons of all professions and in every sphere of life. The design of the following Treatise is to furnish a short yet connected and comprehensive view of these departments of knowledge, which may serve as an introduction to a more extended study, either of the whole or of particular portions. The Work is divided into Two Parts,—the first of which, on the Physical Sciences, contains a view of the more important laws of the material universe, with a few of their more remarkable applications, whether to works of art or to the explanation of natural phenomena. In the Second Part will be found a sketch of the history of nature in the three great kingdoms of Minerals—comprising of course the land, water, and atmosphere—of Plants, and of Animals; concluding with Man, the head of the earthly creation.

From its limited nature, the Work is very much condensed, and some important subjects are, on account of their abstruseness and difficulty, altogether omitted. It is hoped, however, that it contains enough to show the student the richness of the fields here laid open to him, the attractive nature of many of the subjects treated, and the great advantages to be derived from an acquaintance with them. Even to the more advanced such a recapitulation may not be without use; whilst the very numerous Engravings by which every part of it is illustrated, will materially aid those who are entering on the study of these important sciences.

Edinburgh, *January* 1844.

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INTRODUCTORY BOOK OF THE SCIENCES.

PART I.

Physical Sciences.

SECTION I.—GENERAL PROPERTIES OF MATTER.

BY MATTER we understand that substance which composes the various objects that surround us in nature, and which we observe by means of our senses. It is through affecting these,—that is, by acting on our organs of sight, touch, taste, smell, or hearing,—that matter is made known to us; and its properties are only another name for its power of exciting various sensations in our minds. Some of the properties of matter have been thought necessary to its very existence, and have on this account been named essential or primary properties; whilst others, which might be changed or altered without destroying the body, have been termed secondary. The former are principally extension, figure, impenetrability, divisibility, and power of motion; the latter, colour, heat, and some other such qualities; but the distinction is not one of much consequence, especially in physical science. EXTENSION is that property of matter by which it fills a portion of space; and as a body cannot do this without excluding every other, it is said to possess IMPENETRABILITY. It is in consequence of this that one body can rest on another without sinking into it; or when we press two together, that they are not lost in each other, however great the force we may employ. When a vessel is full of water, if we push a piece of wood, or drop a stone into it, as much water must run over as is equal in size to the wood or the stone. The water that fills it must also have displaced the air it formerly contained, and could not enter till this was done. Hence, when a glass is forced under water with its mouth downwards, the air it contains prevents the water from rising and filling the glass, which it does whenever it is placed in such a position that the air can escape. The DIVISIBILITY of matter is the possibility of cutting or dividing it into many parts; and as we cannot conceive of any portion of matter so small that it might not be divided, it is common to say that matter is infinitely divisible, or may be separated into as many parts as we choose. Properly speaking, however, the

division is always finite; and it is thought probable that in reality there are certain limits beyond which matter cannot be divided. It then forms bodies named atoms, from a Greek word meaning fine indivisible particles; but these cannot be seen by our eyes, even when aided by the microscope; and we can always imagine something smaller than the minutest portion of matter we behold. A few examples will show how far bodies have actually been divided. Common writing-paper is only one-250th part of an inch thick, and goldbeater's skin is six times thinner, whilst gold itself may be beat out till one grain covers fifty square inches; and it would take nearly three hundred thousand leaves, laid above each other, to have the thickness of an inch. The gold wire used for embroidery is silver covered with gold, which is only the four or five millionth part of an inch thick. In nature, matter is also very minutely divided. The finest human hair is about one-600th of an inch in diameter; the thread of the silkworm is ten times finer; and that of some spiders only the 30,000th of an inch. Some animals are so small as to be invisible by the naked eye; yet with a powerful microscope we can see that they have various organs and vessels, in which, as in our veins, fluids circulate; and when they are placed in water coloured with carmine, the grains of this substance which they swallow may be seen in their stomachs, necessarily reduced to exceedingly minute particles.

Porosity is also a general property of matter, or rather of bodies as we find them in nature. The particles of matter seem to adhere to each other without being in actual contact, at least in all their parts; and hence vacant spaces or pores are left among them. In solid bodies, such as wood and stone, these pores are often filled with air, water, or other fluids; and their existence may be shown in various ways. Thus, a stream of air or mercury may be forced through a piece of dry wood, the mercury falling in a fine shower. A lump of marble or granite when placed in water under a receiver, gives out a large quantity of air when that above it is exhausted. Mercury by a slight pressure may, in like manner, be forced through a piece of leather; and the human skin is also perforated with numerous pores. The Contraction and Expansion of bodies, or their capacity of increasing and diminishing in bulk, also shows the existence of pores or vacant spaces among the particles of which they consist. Thus, air may be reduced by pressure, as in the chamber of an air-gun, to a fiftieth or eightieth part of its original bulk; while, on the other hand, in the receiver of an air-pump it expands in far more than these proportions. Water also contracts and expands by pressure, though in a degree many thousand times less than air. Solid bodies also are influenced in the same

way, and diminish in bulk by means of pressure. Some are more easily affected than others, and are named soft; others require greater force to make any sensible impression on them, and are therefore termed hard; whilst those which recover their original form when the pressure is removed are said to be elastic. Bodies, we have above said, consist of numerous small particles or atoms, and among these numerous vacant spaces occur. How, then, it may be asked, are these united, and what prevents them from falling asunder like a handful of dry sand? It might seem that if no external force kept them united, they should all separate from each other even by their mere weight. Such, we all know, is not the case; and as it is no external force that keeps them in union, it must be some internal one. This has been named COHESION; and the particles are said to cohere to each other. Each particle of matter seems to be attracted towards every other, like filings of iron to a magnet or loadstone, and through this property all coalesce into one mass. That this power may act, however, it is necessary that the particles be brought very close together. Hence, two pieces of lead when merely laid on each other do not adhere, but if firmly pressed together can with difficulty be separated. Two pieces of iron also when heated and hammered are brought into close contact, and then cohere or are welded together. Many substances when broken into fine powder, however we may press them, cannot be brought so near as to re-unite; but when melted this happens, and they again form a solid mass. Heat seems to prevent bodies from contracting into the smallest possible space, and to repel their particles from each other, as shall be afterwards explained.

INERTIA is that property of matter in consequence of which it is incapable of changing its state, whether of motion or rest. A body when moving cannot stop itself or change its motion, but, unless acted on by some other body from without, would go on moving in the same direction and with the same speed for ever: neither, if at rest, can it begin to move of itself, but requires some external force to set it in motion. Hence no one expects that a stone lying on the ground or a book on the table will begin to stir of its own accord. We are, however, apt to imagine, that an inanimate body when in motion would stop of itself; but this is incorrect, for it is only the obstacles it meets with that cause the ball rolled along the ground to stop, or the stone thrown from the hand to come to the earth. Hence, the fewer impediments, or the smoother the ground, the farther will the ball roll. This property also makes a body take some time before it can be put in motion, or have its motion stopped or changed. Thus, the pieces of money represented in Figs. 1 and 2, as resting on a card and

Fig. 1.

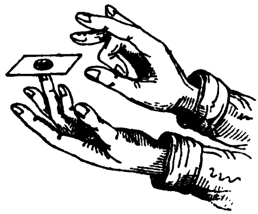
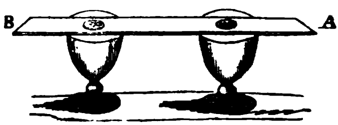
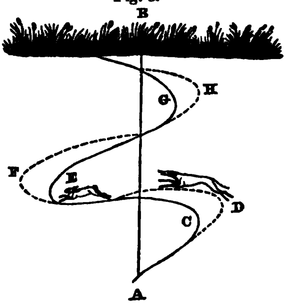


Fig. 2.



a thin slip of wood, do not yield to the motion communicated by a smart blow at one end to the card or the wood, but remain on the finger, or fall into the glasses. Hence, a person in a carriage suddenly stopped is thrown forward, or if riding fast is pitched from his seat. A body in motion also tends to move in a straight line, as a stone in a sling, which, though whirled round in a circle, flies off in a direct course whenever it is allowed to escape. A hare also often makes its escape by taking sudden turns in a new direction for which its pursuer is not prepared. Thus, as shown in Fig. 3, in running to the cover B, the hare takes the direction A C E G, while the dog is obliged to follow that of A D F H.

Fig. 3.



The power of being moved, or *Mobility*, and the possession of *Weight*, are often termed contingent properties of matter, as they do not necessarily form part of our notion of it. All bodies, however, that we find on the earth have these two properties. The ponderability, gravity, or weight of bodies, depends on the power which the earth has of attracting or drawing them towards itself. That some bodies are heavier than others results from there being more matter in them than in those that are light. Weight depends on the attraction of the earth, and varies with the distance from its centre, as is shown by many experiments. A piece of lead of a thousand pounds weight on the surface of the earth would lose two pounds when carried to the top of a hill four miles high, and one pound if taken as deep into the interior of the earth, there being then less matter below to draw it downwards. If removed from Edinburgh to the Pole,

where it would be brought nearer the centre, it would gain three pounds; but if conveyed to the Equator, it would lose four pounds, being then more distant. Every known body has weight, and air or smoke only rise because they are pushed up by something heavier; as, in the same manner, wood which falls in air that is lighter, rises in water which is heavier than itself. These are the general properties of matter; and the science that treats of them is sometimes named Somatology—from two Greek words meaning a discourse of body.

Section II.—STATICS AND DYNAMICS.

By Statics, from a word meaning to stand, is understood a knowledge of those conditions in which bodies will remain at rest. The most general principle is, that they will do so when all the forces acting on them in opposite directions are equal, or when the power tending to move them in one direction is met by an equal power tending to move them in an opposite direction. The most interesting problem in statics is that concerning the *centre of gravity*, or that point in a body round which all its parts are so arranged that when it is supported the body will remain at rest. In a straight rod of uniform dimensions the centre of gravity is evidently the middle, and in a circular body the centre. In irregular masses of matter it is more difficult to find, but this may often be accomplished by repeated experiments. In bodies placed on a plane, or on the ground, when the centre of gravity is supported, or when the vertical line from it to the ground falls within their base, they will stand, as in Fig. 4; but when this is not the case, as in Fig. 5, they will fall.

Fig. 4.

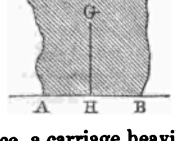
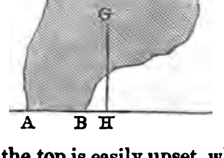


Fig. 5.



Hence, a carriage heavily loaded on the top is easily upset, whilst one where the greater part of the weight, and consequently the centre of gravity, is placed low, may be considerably inclined without danger, as seen in Fig. 6, where G is the centre of

Fig. 6.

Fig. 7.

gravity in two different positions. The danger incurred by not attending to this rule is well illustrated by Fig. 7; from which it is evident, that by leaning a little backwards, or even putting his hands behind him, the boy would overturn the chair and fall to the ground. People rising up in a boat when they think it in danger of upsetting, actually increase the risk, by raising the centre of gravity, and rendering it more apt to overturn than if they had kept their places. Rope-dancers frequently use a long

Fig. 8.

pole loaded with lead at the ends, by shifting which from side to side they are better able to preserve their balance (Fig. 8),

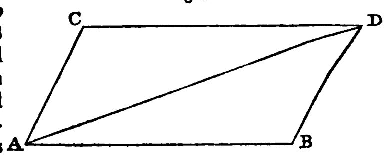
in the same manner as a person walking on a narrow plank puts out his arm or leg to one side when he feels himself falling towards the other. Practically, all men have a certain knowledge of statics; but many severe accidents often happen from want of acquaintance with the principles of the science or inattention to them.

Dynamics, derived from a word signifying force or power, is the general science of bodies in motion, as statics is of those at rest. The laws of motion arise from the inertia of matter, which, as we mentioned, prevents it from beginning to move of itself, or changing either the velocity or direction of its motion. It also results from this, that bodies must move in a straight line, unless turned aside by some resisting power, when they will deviate from their course more or less according to the amount of the force and the direction in which it acts. The third general law of motion or force is, that action and reaction are equal, or that whatever force one body exerts on another, that other exerts an equal force on it. Thus, any heavy body laid on a table presses it down; but the table reacts on the weight, and pressing it as much upwards, both remain at rest. So also, when a ball in motion strikes another at rest, the first loses a part or the whole of its motion, which is communicated to the second. Motion is either uniform or variable: in the former case, the body passes over equal spaces in equal portions of time; in the latter, this does not happen, and its motion is said to be accelerated when it always moves over a greater space, or retarded when it moves over a less space, in successive equal portions of time. There are therefore three things to be regarded in a body in motion—the space it moves over, the velocity or speed with which it moves, and the time occupied by it in moving. The velocity is measured by the space or number of feet in length over which the body moves in a second of time; and hence, in bodies moving uniformly, the space they traverse is equal to the velocity multiplied by the time counted in seconds. Where the motion is uniformly accelerated, to find the space moved over, the velocity during the first second must be multiplied by the square of the time. Thus, a stone falling from a high tower moves rather more than sixteen feet during the first second; in two seconds, four times that, or sixty-four feet; and in three seconds, nine times that distance, or 144 feet. The momentum of a moving body, or the amount of its force, is measured by its velocity multiplied by its weight or the quantity of matter it contains. Hence, two balls, one three pounds weight moving with a velocity of one foot in a second, and the other one pound weight with a velocity of three feet, would have equal momenta, and if meeting directly would destroy each

other's motion. If the balls were elastic, that is, when compressed had a tendency to resume their former dimensions, they would recoil or spring back in the opposite directions; if they were non-elastic, they would remain at rest together.

The composition of forces is a very important principle. Where one force acts on a body, it will evidently move in the direction of this force; but where it is acted on by two or more forces, it must take an intermediate direction. Thus, in Fig. 9, if one force were acting on a body at A so as to make it move to B in a certain time, and another force so that in the same time it would move to C, it would follow neither of the lines A B, A C, but take an intermediate course, A D; which is named the resultant or equivalent of the two former, and is the diagonal of the parallelogram of which they are the sides.

Fig. 9.

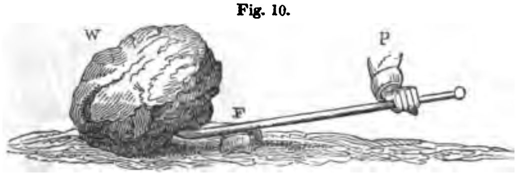


From this figure it appears that neither of the forces is lost, but that the result is exactly the same as if each had acted successively on the body during equal intervals,—the one carrying it from A to B, the other from B to D; or reversely, the latter taking it from A to C, and the other from C to D. This composition of forces may be illustrated by dropping any thing in a carriage or a ship in motion, when it will be observed to strike the same point as if the carriage or ship were at rest. So in feats of horsemanship, when the man and the horse are moving with great speed, the former can spring up from and again alight on the same part of the saddle, his upward motion not altering that which he derives from the motion of the horse. Hence, in leaping through a hoop, the performer has only to spring directly upwards, and the impetus he has received from the motion of the horse carries him through the hoop. Composition of motion is well exemplified by a person walking on the deck of a vessel under sail, where his motion is compounded both of that of the vessel and of that derived from his own exertions.

Section III.—MECHANICS.

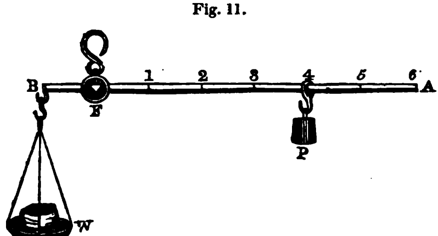
The general principles of the two sciences treated of in the last section, when applied to solid bodies found on the earth, and especially to the construction of machines, are named Mechanics. This term, however, is often used as comprehending both the former, and embracing the whole laws of rest and motion in solid bodies; but here we shall take it in the more limited sense. The first elements of machinery are the mechanic powers, of which there are usually reckoned six, though some of them are in truth only modifications of one. The first is the lever, of

Fig. 10.



which the common crow-bar (Fig. 10) is a good example—the hand P moving it being the power, the stone F on which it rests the fulcrum, and the block W to be raised the weight. The power and weight are so related that they balance each other, when the product of one multiplied by its distance from the fulcrum is equal to that of the other. Thus, supposing the stone to weigh 1200 lbs., its distance from the fulcrum six inches, and the hand twenty-four inches distant to press with a force equal to 300 lbs., then the one would just balance the other, 1200 multiplied by 6, and 300 multiplied by 24, being each equal to 7200. By slightly increasing the pressure, or moving the hand further from the fulcrum, the weight would be overcome and the stone raised from the ground. The balance is a lever whose arms are equal; while those of the steelyard are unequal, and articles are weighed by moving a certain weight to a greater or less distance

Fig. 11.



from the fulcrum or point where it is supported. In Fig. 11, the distance between F and P is four times greater than that between F and B, and therefore it would require four pounds at W to balance one pound at P. There are other kinds of levers, in which the power, weight, and fulcrum change places; but the principle in all is the same, the power multiplied by its distance from the fulcrum being always equal to the weight multiplied by its distance.

The wheel and axle is only a modification of the lever, as is

Fig. 12.

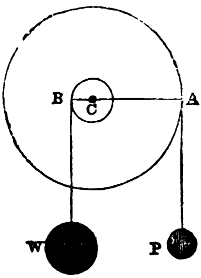
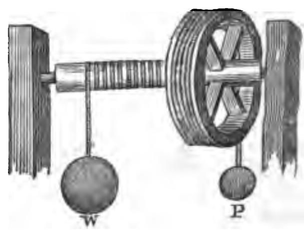


Fig. 13.



shown in Fig. 12, which represents a section of Fig. 13, the great difference being that the weight and power are connected to the lever by means of ropes. The common windlass (Fig. 14) is also a variety of this, a handle being substituted for the

Fig. 14.

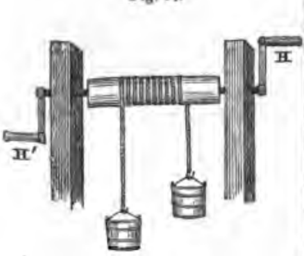
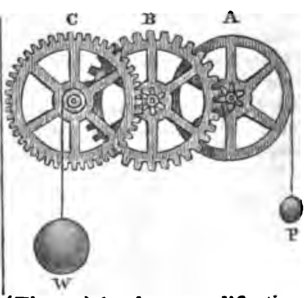


Fig. 15.



wheel. The wheel and pinion (Fig. 15) is also a modification of the same power, and is very extensively used in machinery. The small wheel is named the pinion, and the power gained is proportional to the difference in the diameter of the wheels, or to the number of equal-sized teeth on each. Where there are more than one set, it is in the proportion of the radii of all the

wheels to that of the radii of all the pinions. It is to be observed, however, that in this and all the other mechanic powers there is always a loss of velocity proportional to the gain of power; and, in this example, the large ball W ascends slower and over a shorter distance than the small one P descends, in proportion to their weights.

In the pulley a rope or chain passes over a small grooved wheel turning freely on its axis. Where there is only one pulley (Fig. 16), no power is gained, and only the direction of the motion is changed, the two weights being exactly equal.

Fig. 16.

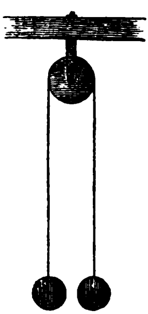
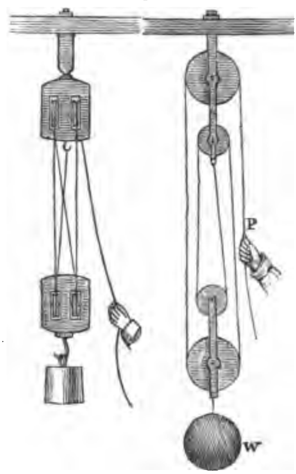


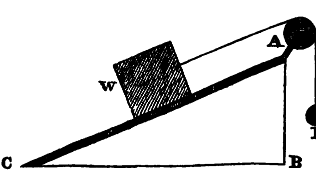
Fig. 17.



By combining them, however, power is gained; and in this combination (Fig. 17), one pound at P would support four at W.

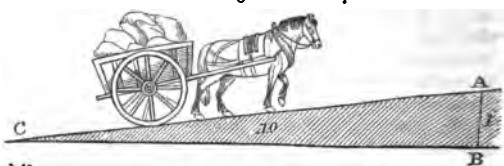
In the inclined plane (Fig. 18), the weight is to the power in the same proportion as the length of the plane is to its height, or as the distance C A is to that of A B. The most common and useful application of the inclined plane is to the construction of roads, the force necessary to drag a load up an acclivity in-

Fig. 18.



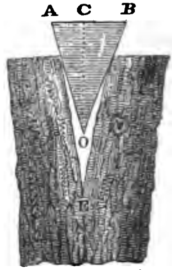
creasing in proportion to the slope. Thus, in Fig. 19, the horse must exert an additional force equal to one-tenth of the whole

Fig. 19.



load while ascending C A, the rise being one in ten; or the line A B one-tenth of the whole distance travelled. A stair is also a variety of the inclined plane.

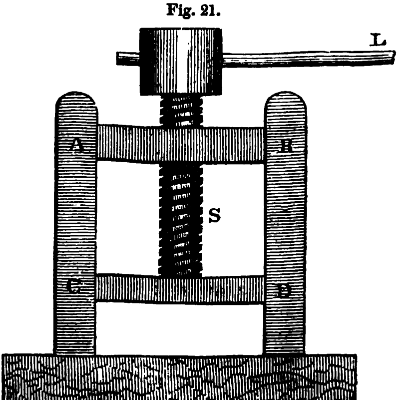
Fig. 20.



The wedge (Fig. 20) resembles two inclined planes joined together, and is used for splitting wood or stones. The finer the edge, or the greater the length of the wedge compared to the thickness of its back, the more powerful is it found to be. The force, however, communicated to it by a blow is of a peculiar nature and not easily calculated. Most edge-tools are varieties of the wedge, particularly axes, knives, and chisels; whilst scissors are a combination of the wedge and lever.

The screw is in some measure a modification of the inclined plane, as may be seen by cutting out a section of the latter in paper and rolling it round a pencil, when it forms a screw. In Fig. 21, where S is the screw, and A B the nut in which it works, it is combined with the lever L, forming the handle by which the screw is turned. It is used for pressing things or raising heavy weights, and its power is proportional to the distance between the threads of the screw

Fig. 21.



compared to the circumference of the circle described by the lever. Thus, if there are four threads in an inch, and the handle moves round a circle of fifty inches, then the force gained will be four times fifty, or two hundred. It is also much employed for measuring small distances, the space passed over by the lever, or index as it is then named, being much greater than that by the screw; and therefore a large division, which can be easily seen in it, corresponds to a small one in the screw.

Out of these simple elements the most complicated machines are constructed. The watch, the steam-engine, the power-loom, or the calculating machine, are but various modifications and combinations of these simple powers; and chiefly of the lever, the wheel and pinion, and the screw. Machinery is a means of turning power into other and more profitable directions; of making it work with more advantage, and to a better purpose; but it does not of itself give or increase power. When a man with a lever moves a stone which unaided he could not have stirred, or raises a weight far surpassing his natural powers by means of a pulley, he is still the source of the whole force; there is no power but what is derived from him. So far from giving power, in using machinery part of it is always lost in overcoming the various passive or resisting forces it encounters. Thus, a carriage passing through the air, or a boat through the water, meets with resistance from these fluids. But there are other resistances which have greater influence on machinery, and modify still more the effects that result from it. These are, the inertia or weight of the matter composing it, the rigidity of the ropes which enter into its construction, and especially the friction of its various parts. The weight that, according to theory, should pull another up an inclined plane, is from its friction unable to move it; and the same is true of the lever, wheel, and pulley. Friction acts as a uniformly retarding force, and when the force impelling any machine is withdrawn, tends gradually to bring it to a state of rest. The greater the friction the sooner this occurs, as a carriage freed from the horses would stop sooner on a level road than on a railway, and also requires more power to set it in motion on the former than on the latter. Friction is, however, of great utility in nature, as without it we could not stand on a plane, however slightly inclined; all bodies would slip down to the lowest level, and walls or houses could hardly be erected. Much of the utility of screws and nails arises from friction, so that man gains far more by it than he loses.

As machinery does not act by itself, but must be set in motion by some external agent, it may be useful to recount the more important of these. The labour of men and animals is one of the first employed of the prime movers. There are a vast num-

ber of simple machines set in motion by human power, and man finds them necessary in almost every action of his life. Knives, scissors, needles, spoons, forks, and many other utensils in constant employment, are machines no less than the steam-engine or power-loom, and like them intended to lessen human labour. Wind is also a first mover, as in the windmill, and especially the ship, where the sails are a machine communicating the motion of the air to the vessel. Water is likewise an important source of power, for which we are indebted to the kind beneficence of Providence. The clouds, which rising from the ocean float far into the interior of islands and continents, not only refresh the ground, but, flowing back in innumerable streams, furnish an unwearied and unfailing source of power of almost incalculable amount. Steam has in recent times become one of the most powerful first agents, and one that is most easily and usefully employed by man. Its recent discovery, and the innumerable applications made of it, show the possibility of other powers no less important being yet reserved for man.

Section IV.—HYDROSTATICS AND HYDRAULICS.

Water and air are the two most familiar examples of fluid bodies. Both differ from solids in the great mobility of all their particles, which have no sensible magnitude, and yielding to any force impressed on them, *flow* easily into any channel. Fluids are divided into two classes: liquids, comprising those like water, oil, or mercury, which can be retained in vessels open above; and airs or gases, which cannot be so retained, but expand and mingle with the atmosphere. Hence they were formerly named elastic and non-elastic fluids,—the latter comprehending water and similar bodies; but these are now found also to yield to pressure, and taken strictly these terms are no longer applicable. Water, when the pressure of the atmosphere, amounting to about fifteen pounds on every inch of surface, is removed, expands about one part in 22,000; and when sunk in the sea to five hundred fathoms, where the pressure is 1300 pounds, it is compressed one-27th part of its volume. The principal property of liquids is their equal pressure towards all sides. Each particle in a fluid at rest presses equally in every direction, and is equally pressed by those around it or by the sides of the vessel with which it is in contact. It also presses upwards with the same force as downwards; and the pressure on the sides of the vessel is equal to that on the bottom at the same depth.

Hence, in an irregular shaped vessel like that represented by the dark part of Fig. 22, the pressure on the bottom would be just the same as if the vessel were of a regular shape N D C O; and were the whole space above the line D K F A filled with water, the pressure would neither increase nor diminish. This is evident from a particle of water at K being as much pressed by the side of the vessel as it would be by a column of water equal to L K. Hence also where two vessels communicate, as in Fig. 23, the water in both will stand at the same level, whatever be the difference of their size. On this also depends the principle of the hydrostatic bellows (Fig. 24), in which a small quantity of water

Fig. 22.

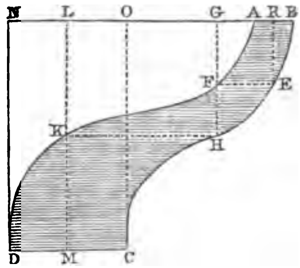


Fig. 23.

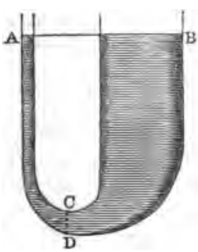
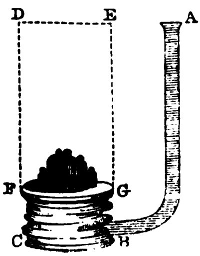


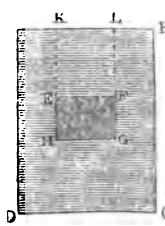
Fig. 24.



in a narrow tube is made to raise a weight equal to that of the water that the space above would have contained. Bramah's hydrostatic press is similar to this, only the water in the small tube is pushed down by a piston.

When a body is immersed in a fluid, as water, the pressure on it is equal to the weight of the water above, as in Fig. 25, where the pressure on the side E F is equal to a column of water K E F L, and that on H G to a column K H G L. Hence, if the body is lighter than water, the pressure below is more than that of the column of water above and its own weight, and it has a tendency to float; whereas, if it is heavier, the pressure downwards will be greater, and

Fig. 25.

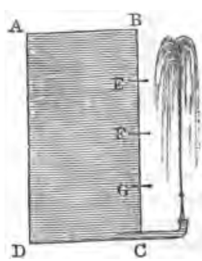


it will sink. Any body immersed in water loses as much of its weight as that of the liquid it displaces, and this whether it sinks or floats. In the latter case, the water displaced is equal to the weight of the body; in the former it is less. It is thus that the specific gravity of solid bodies, or their relative weight to water, is found (Fig. 26). They are first weighed in the air, and then in pure water, when the difference of weight being that of the same volume of this fluid, the proportion between the two is easily found. These and similar problems are treated of under Hydrostatics—a name derived from two words implying the balance or stability of water.

Fig. 26.

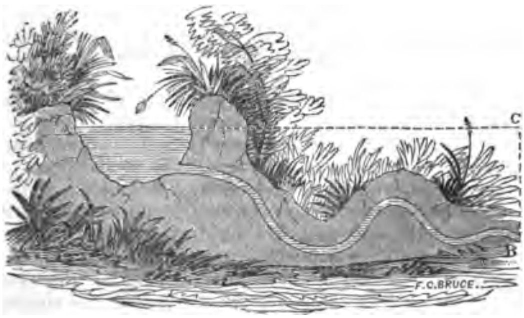
Hydraulics, on the other hand, from two words meaning water and a tube or pipe, treats of the motion of water in these and other channels. The most important inquiry here is the velocity with which water would flow out of any opening in the side of a vessel, when the pressure on it is known. As seen in Fig. 27, when it is allowed to escape and rise up in a jet, the height of this is nearly equal to that of the water in the vessel; and theory also shows that water should run out with the velocity it would acquire in falling from B to C, which, were it not for the resistance of the air, would raise it to the same height. At G, F, and E, the velocity would be proportionally less. The friction of the water on the tube, however, makes the velocity and the amount that runs out at any opening less than it should be by calculation.

Fig. 27.



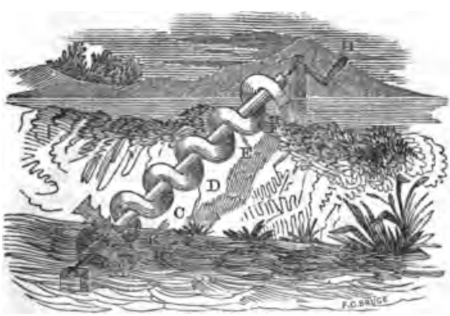
The property of water to rise always to the same height in connected vessels, is made use of to convey it from one place to another, even over considerable inequalities of ground, in close tubes or pipes. Although it descends at one place and rises at another, still so long as the tube is not carried higher than the fountain-head, the water will continue to flow (Fig. 28). Edinburgh is thus supplied with water from a spring about seven miles distant, which passes across several valleys and rising

Fig. 28.



grounds, the place where it begins being about 230 feet above the reservoir on the Castle-hill, whence it is conveyed in other pipes to almost every house in the town. The water-snail, or Archimedes' screw (Fig. 29), is an ingenious instrument for raising water, formed on the principle of liquids always seeking the lowest level. A tube is bent round a cylinder in a screw-like

Fig 29.

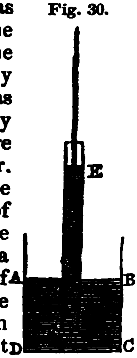


form, and so inclined that the water which enters at A, when the handle is turned cannot escape at the lower end, but being conveyed successively to C D E and F, at last runs out into the cistern above. Other machines for raising water will be mentioned in the next Section.

Section V.—PNEUMATICS.

The name of this branch of science is derived from a Greek word signifying the breath or air, and it treats of bodies of this nature. These are highly elastic, and can be easily compressed into a small space, the density being always proportional to the pressure. Hence air, when pressed by a weight equal to two atmospheres, or one more than is usually upon it, is compressed into half its bulk, and with five times that weight into a fifth. If shrivelled apples, or a bladder partly filled with air, be put into the receiver of an air-pump, when that in the receiver is withdrawn, and the pressure thus removed, the air within the apples or bladder expands so that they become plump and distended. The air which we think so light has also weight, and a bottle full of it weighs more than when the air is exhausted,—the difference, if the bottle holds an English pint, being about eleven grains. The air that rests on the earth, or the atmosphere, as it is named, from two words meaning the sphere of vapours, must therefore have a certain weight. Many things show this, especially the rise of water in a pump, as in Fig. 30, where the water is seen to follow the piston E when it is drawn up. That it is the weight of the air which causes this, is shown by water rising thirty-two feet in a pump; whereas mercury in the barometer only rises about thirty inches, and when taken up a high hill, where there is less air above pressing upon it, falls still lower. This experiment, first made at the suggestion of the celebrated Pascal, is now a common method of measuring the height of hills. The weight of the atmosphere is thus found to be equal to that of a sea of water about thirty-four feet deep, or one of mercury thirty inches deep, covering the whole earth. This is found equal to fifteen pounds on every square inch of surface; and the whole weight of the atmosphere may in this way be calculated. It is thus proved to be upwards of five thousand billion of tons, or equal to the weight of a globe of lead sixty miles in diameter. Its pressure on the human body is also very great, and has been estimated at between twenty and thirty thousand pounds weight on a moderate-sized individual. As, however, it has free access to all parts of the body, both internal and external, this enormous weight is wholly unfelt.

Fig. 30.



Many machines of great use to men depend on the weight of air. The common pump, just mentioned, is one of these. This is shown in Fig. 31, where *p* is the piston working up and down in the upper part of the pipe. There is a valve in the piston, and another at the top of the narrow part of the pump at *b*, both opening upwards, and permitting the water to rise up, but not to return downwards. When therefore the piston is pushed down,

Fig. 31.

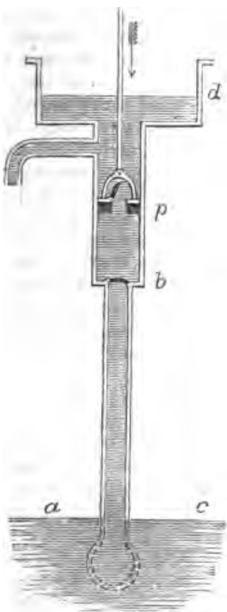
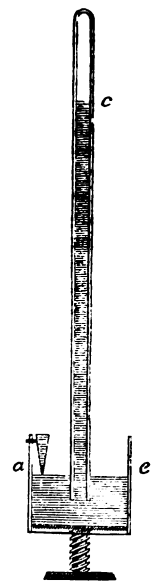


Fig. 32.



and then drawn up, a vacuum is formed, and the air, pressing on the surface of the water at *a c*, forces it to rise. On repeating the action several times, the water at last rises above the piston and flows over. The barometer also depends on the pressure of the air, and the most improved kind is shown in Fig. 32. The tube is first filled with mercury, and then the open end is inverted in a vessel of this fluid *a e*, named the cistern. The mercury then falls in the tube till its weight balances that of the air pressing on the surface of that in the cistern, and consequently

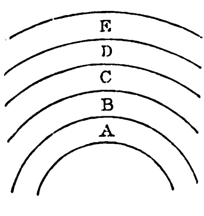
rises or falls as this increases or diminishes. Its height is measured by a scale affixed at *c*; and to keep the height of that in the cistern uniform, a screw raises or lowers the moveable bottom. This instrument is sometimes named the weather-glass, its rising or falling being supposed to indicate dry or wet weather; which, however, is only partially true.

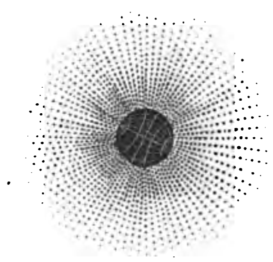
Air expands with heat, its bulk increasing rather more than two parts in every thousand for every degree of temperature. It thus becomes much lighter, and ascends, as is seen in the smoke going up the chimney with the air heated by the fire. Fire balloons are also raised by the same process, the air in them being warmed and expanded. Common balloons also rise because they are filled with a gas lighter than atmospheric air. It is this expansion of air by heat that, as we shall afterwards find, is one great cause of winds, which are only air in motion. The power of this in driving mills, impelling ships, and, when more violent, uprooting trees and overturning houses, shows the weight of air, and the force its minute particles can acquire when their velocity is very great.

Though the barometer, as we have seen, tells us the weight of the atmosphere, yet its height cannot thus be known. As we ascend, the pressure on it from that above becomes always less and less. Thus (Fig. 33), if there be various strata of air, A, B, C, D, E, resting on the earth, A is pressed by the four above it, B only by three, and D only by one, and hence the air

Fig. 34.

Fig. 33.



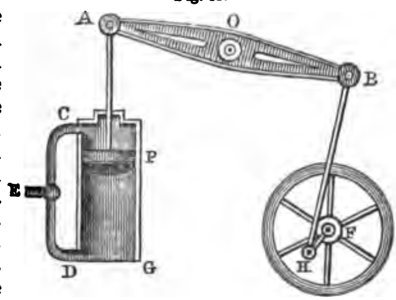


in D will be less dense than that in A, B, or C. This is illustrated by Fig. 34, which represents the earth surrounded by its atmosphere. Different philosophers have estimated this at from fifty to a hundred miles in height; but, as said before, nothing certain is known on this matter.

The steam-engine, now of such importance, also acts by the

expansion of an aerial fluid, which in this case is the vapour of water, or steam. The more important parts of it are shown in Fig. 35, in which C G is the cylinder, P the piston fitting it closely, A B the beam moving on its centre at O, B H the rod turning the fly-wheel by means of the crank H F. A valve at E admits the steam alternately above and below the piston, and is so contrived that when the steam enters above, that below is allowed to escape either into the open air or into a vessel named a condenser, because the steam is there condensed into water. The steam entering above, therefore, presses the piston down; but on reaching the bottom, the valve at E turns, and the steam entering below forces it up again. In this way the beam is made to move up and down alternately, and by means of the crank turns the fly-wheel, and sets the other machinery in motion.

Fig. 35.



Section VI.—ACOUSTICS.

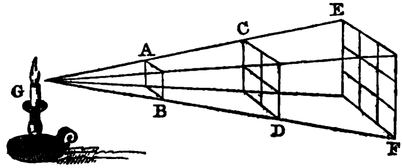
When any elastic body is struck it acquires a tremulous motion; and this being communicated to the air, and by it to the ear, gives us the sensation of sound. Air being thus the general medium of sound, the history of its phenomena, named from a Greek word Acoustics, is closely connected with the subject of the last Section. That air conveys sound to the ear is shown by a bell rung in the receiver of an air-pump always giving a more and more faint sound as the air is exhausted, and at last becoming inaudible. Fluids also convey sound, and the noise occasioned by two stones struck together under water may be heard by the ear if immersed. When the ear is placed close to a beam of wood, the sound of any thing striking the other end of the beam is conveyed through it, though it would be inaudible in the air. Sound moves through air, in its ordinary condition, at the rate of 1130 feet in a second; but the wind, heat, and moisture, make some change on the velocity. Hence, as light moves so fast as to be almost instantaneous, we see the flash of a gun before

the report is heard, and the lightning arrives at the eye long before the thunder reaches the ear. It is usual to calculate the distance of thunder by the duration of this interval, about four and a half seconds being allowed to a mile. Sound is reflected from hard and smooth surfaces like light from a mirror, thus causing echoes, which are simply the sound reflected back from some rock or wall to the place whence it came. Sometimes the sound is re-echoed several times, forming repeating echoes, many examples of which occur in hilly countries.

SECTION VII.—OPTICS.

THIS science is named from a Greek word meaning to see, and treats of the laws of vision and of light. Light is generally produced from the sun or bodies in combustion; but there are other sources whence it proceeds, as electricity; and living animals, as the fire-fly and glow-worm. It moves in straight lines, and hence, as these spread out from the luminous body in all directions, we speak of the rays of light. Its motion is very rapid, being estimated at 192,000 miles in a second; yet it takes above eight minutes to travel from the sun to the earth, and from the nearest of the fixed stars above three years. Some substances are transparent, or permit light to pass through them, as air, water, and glass; others are opaque, and intercept the light. It would, however, appear that this distinction is only partially true, since air, water, and glass, the most transparent bodies known, intercept part of the light. A fourth or fifth of the sun's light, when vertical, is lost in passing through the atmosphere; in water half of it disappears at a depth of from two to six feet; and a thickness of two or three inches of the finest glass would have the same effect. Gold and silver, on the other hand, usually supposed to be opaque, in thin plates transmit light,—the former of a green, the latter of a purple colour; and we may believe that, if made thin enough, other bodies would do the same. As the rays of light from any luminous body are more widely spread out as the distance from it increases, so also its brilliancy must diminish. The manner of this diminution may be understood from Fig. 36, where it is evident that the light which at A B fell upon one square, at C D, or double that distance, would

Fig. 36.



have four squares to illuminate; and at E F, or three times the distance, nine squares. The number of squares is thus always the square of the distance, or this multiplied by itself; and as the intensity of the light must diminish by being diffused, it is said to do so ***inversely as the square of the distance;*** that is, it increases as the square of the distance diminishes, and diminishes as it increases. The direct light of the sun has been estimated to be equal to that of 5563 moderately sized wax-candles placed within a foot of the object; whereas that of the moon is only equal to one candle at a distance of twelve feet, or three hundred thousand times less.

The principal phenomena of light arise from its reflection or refraction. That branch of optics which treats of the former is named catoptrics, from a word meaning a mirror. When a ray of light falls on a plane mirror, it is reflected at an angle equal to that at which it fell on it, or the angle of incidence, as it is named. Thus (Fig. 37) the ray C D is reflected from the mirror A B in the line D E, which makes an angle with A B, or

Fig. 37.

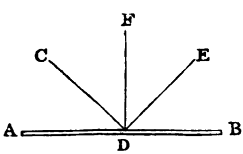
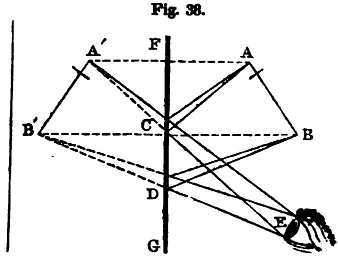
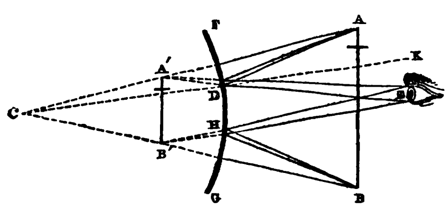


Fig. 38.



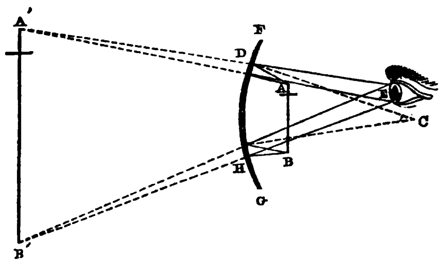
its perpendicular F D, equal to that made by C D. As we judge of the position of objects by the direction in which the light from them meets the eye, an object, as A B in Fig. 38, is seen as if placed at A′ B′ behind the mirror F G, and inclined in an opposite direction. The same laws are also true of reflections from spherical mirrors, of which those from a convex surface

Fig. 39.



(Fig. 39) appear diminished, and those from a concave surface (Fig. 40) magnified. Concave mirrors are used as burning-

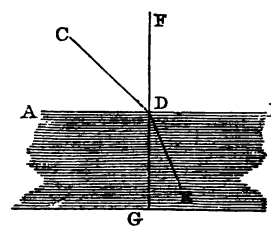
Fig. 40.



glasses for collecting the rays of the sun to a point or focus, when wonderful effects are produced. They are also employed in the construction of reflecting telescopes, for which purpose much accuracy of form is required.

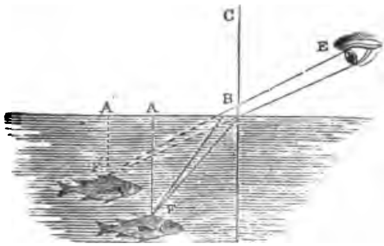
Dioptrics, from a word meaning to see through, is that branch of optical science which treats of the phenomena of light when passing through transparent bodies. When a ray of light falls on a flat surface of glass or water perpendicularly, it continues the same course; but when it falls on it obliquely, it is bent or refracted from its course, as C D E, Fig. 41. In passing out of air into a denser substance, or medium as it is called, as water or glass, the ray of light is bent nearer to the perpendicular, and when passing from a denser to a rarer, farther from it. Hence, in looking at any body in the water, as a fish or a stone, it appears higher than it is in reality, and consequently the water seems less deep, and this by about one-fourth of the whole distance; or if A F (Fig. 42) is four feet, A′ F′ is only three. This effect of water in raising the image of an object is well seen by dropping a piece of money into a vessel, and then lowering the eye till it is concealed by the side. On filling the vessel with water it will again appear as if raised up from the bottom. It also

Fig. 41.



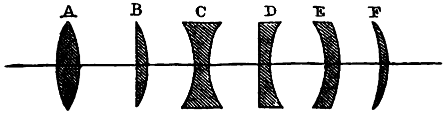
occasions many accidents, by making a clear river seem less deep than it is in reality. Refraction also alters considerably the apparent position of the heavenly bodies, the various strata of the air having different densities, and thus affecting the light like different media. The stars when near the horizon are raised up, the sun and moon appear oval, their lower side, or limb, as it is named, being raised more than the upper one; and it also makes these luminaries rise earlier and set later than they would otherwise do; so that the long winter night of the polar regions is thus shortened several days.

Fig. 42.



A ray of light in passing through a flat piece of glass being refracted both on entering and leaving it by the same angle, but in opposite directions, has the same direction both before and after leaving it. But when small pieces of glass, or similar transparent substances, are cut with one or more spherical surfaces, various phenomena are produced. These are named lenses,

Fig. 43.



and are of various forms (Fig. 43); as, A the double convex, B the plano convex, C the double concave, D the plano concave, E the concavo convex, and F the meniscus. The first, A, is the common magnifying glass, and collects the rays that pass through it to a common point or focus beyond (Fig. 44).

Fig. 44.

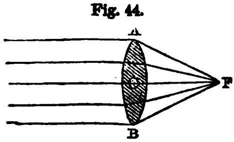
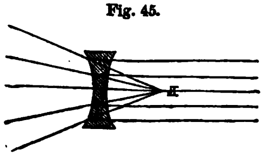


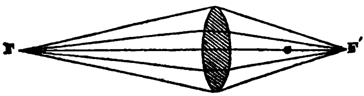
Fig. 45.



In a concave lens, on the other hand, the rays are made to diverge, or spread out wider, as seen in Fig. 45. In these

figures the rays of light are represented parallel to each other, like those from the sun, and the point where they converge is named the principal focus. Where they proceed from some luminous body near the lens, they sensibly diverge from each other, as in Fig. 46, and therefore are longer of being united to

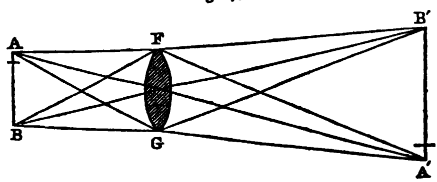
Fig. 46.



a focus. In this case, F and F′ are named conjugate foci, and the place of the one depends on that of the other; F′ approaching nearer to the place of the principal focus as F recedes further from the lens.

The principal use of lenses depends on their forming a distinct image or picture of any object seen through them. The rays of light after passing through the lens are again arranged in similar order on its opposite side, and when received on the eye, or on a sheet of white paper placed behind the glass, are seen to form an exact image of the object whence they proceeded. This is illustrated by Fig. 47, where the rays from the points A and

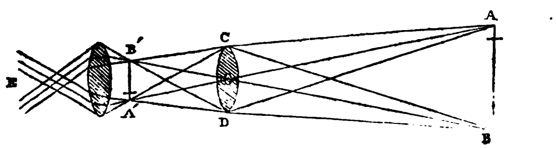
Fig. 47.



B are shown, after passing through the lens F G, to be again united in the points A′ and B′, corresponding to its opposite focus. The concave lens (Fig. 45) diminishes the object, or makes the rays appear as if proceeding from a smaller space; whereas the former increases or magnifies the object, and is commonly named a microscope or magnifying-glass. The principle on which this property depends is, that any object seems to increase in size as we bring it nearer the eye, but at less than six inches cannot in general be seen clearly. At a shorter distance rays of light enter the eye with so much divergence, that it is unable to bring them to a focus on the retina so as to form a distinct image. A convex lens, however, causing the rays from any object placed in the focus F (Fig. 44) to enter the eye parallel, gives it this power and enables us to bring an object

nearer than six inches, and hence to see it larger than reality by as many times as it is brought nearer. Hence, where the focal length is two inches, the glass magnifies three times, or makes the object appear thrice as long and broad as it is in reality, and hence with nine times its superficial dimensions: where the focal length is one inch, it magnifies the object six times in linear and thirty-six times in superficial dimensions. In the compound microscope two glasses are used, one of which enlarges the image of the object, whilst the other enables us to bring that image nearer to the eye. The magnifying power of such an instrument far surpasses that of the simple lens, and objects are seen many hundred times larger than in reality. It is by means of it that the interior structure of animal and vegetable bodies has been made known to the physiologist, and that naturalists have discovered, we may almost say, a whole world of animated beings so minute as wholly to elude our unaided vision. Another instrument of similar construction has, on the other hand, made known innumerable bodies, which, though of immense size, would have been for ever concealed from us by their remoteness. This is the telescope (Fig. 48), which, as used in astronomy, has also only two glasses, one of them, C D,

Fig. 48.



named the object-glass, forms an image A′ B′ within the tube, which by means of the other glass is seen very near, and therefore though in reality smaller, yet apparently larger. The image, however, is, as seen in the figure, inverted, and this kind of instrument is only used in astronomy, where this is a matter of no consequence. In the telescope as first employed by Galileo, the eye-glass was a concave lens, like C in Fig. 43, by means of which the object was restored to its natural position. This instrument has some defects, and is now seldom used except in opera-glasses. The usual telescopes for viewing terrestrial objects are now made with an eye-glass composed of four lenses, by which the object is seen in its true position. Such telescopes are named refracting; but there are others in which the image is formed by being reflected from a concave mirror or speculum of metal, and seen by an eye-glass as in the former kind. The large telescope with which Herschel made many of his important discoveries was of this construction.

The human eye also resembles a very skilfully contrived opti-

cal instrument. It is of a globular form, and enclosed in several coats, the outer one being named from its hardness the sclerotica. To this the various muscles by which the eye is moved are attached. Its several parts are shown in Fig. 49, where C C′ is the cornea, a transparent horny substance; the space behind A is filled with a clear fluid, named the aqueous humour; D D′ is the iris or coloured part of the eye, in the centre of which is a circular opening named the pupil; E F is the crystalline humour, more consistent or firmer than the former, and shaped like a double convex lens; V is the vitreous humour, named from its resemblance to liquid glass; O is the optic nerve, which, spreading out on the retina or net-work lining the back of the eye, conveys the impressions formed there, in a way unknown to us, to the brain and mind. All the light which enters the eye is admitted by the pupil, which enlarges or diminishes so as to regulate this, retaining, however, at all times its circular form. It expands where the light is feeble, and contracts where it is strong; and hence, in passing suddenly from darkness to light, or the reverse, some time is required before the eye can suit itself to its new circumstances. In an eye which possesses distinct vision, the rays entering at the pupil form a distinct image on the retina, as at A′ B′ in Fig. 50, where F G is the lens of the eye. In old

Fig. 49.

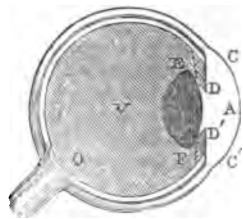
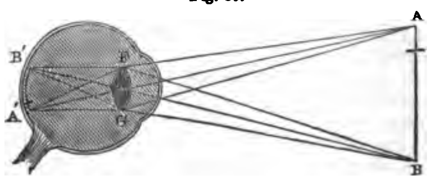
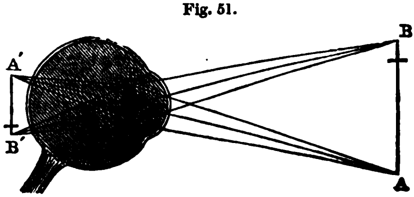


Fig. 50.



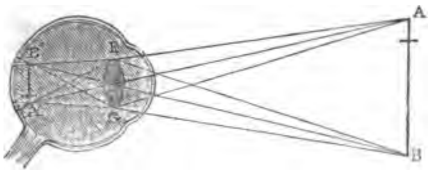
people the eye becomes too flat, and a distinct image would only be formed behind the retina, as at A′ B′ (Fig. 51); and hence

Fig. 51.



convex glasses, or common spectacles, by causing the rays of light to converge sooner, enable them to see more clearly. In short-sighted people the lens of the eye is too convex and the image is formed before reaching the retina (Fig. 52), and hence

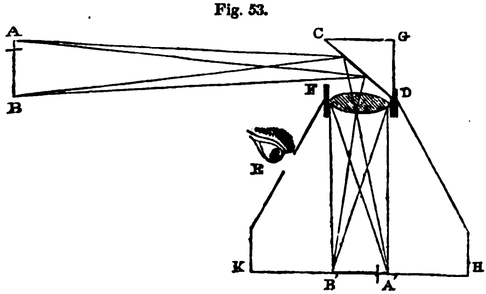
Fig. 52.



they require concave glasses to throw it farther back. These simple instruments are one of the greatest gifts which modern science has conferred on mankind, and may almost be said to give new eyes to the blind. The name of the inventor is unknown, but they are supposed to have been in use in the end of the thirteenth or the beginning of the following century.

The camera obscura, which formerly was little more than an ingenious optical toy, principally employed for amusement, has recently, from the discovery of a method by which the fleeting pictures it forms may be fixed and preserved, become of very great importance. Its principle will be easily understood from Fig. 53, though various other constructions are often

Fig. 53.

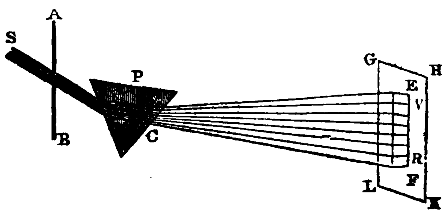


adopted. F K H D is a box, stained black in the inside to destroy all reflected light. At the top is a sliding piece, containing a sloping mirror C D, and a common convex lens F D. The rays of light from any object A B are reflected from the mirror to the lens F D, and collected by it to a picture at the focus within the box; and, by raising or lowering the lens according to the distance of the object, its image is thrown dis-

tinctly on a sheet of white paper, spread on the bottom of the box, and seen by the eye through a small opening at E. The only use of the mirror is to alter the direction of the rays of light, the figure being entirely formed by the lens. In the invention of Daguerre the picture is formed on a plate, the surface of which is by a chemical process rendered capable of being permanently affected by the action of the rays of light.

Another department of Optics is named Chromatics, as treating of the nature and origin of colours. The light from the sun is pure white, whereas the various bodies around us exhibit a vast variety of colours and tints. If a small hole be made in

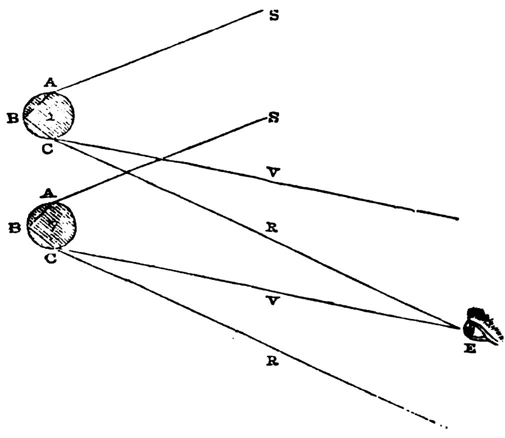
Fig. 54.



the window-shutter of a dark room, as in A B, Fig. 54, a ray of light will enter. This forms a round and white image when received on a sheet of paper; but if it be intercepted by a prism or angular piece of glass P, the light no longer proceeds in a straight line, but is bent upwards and spread out, forming a ribbon long and narrow like E F. This, however, is no longer white, but striped with various colours, of which Newton, who first gave an explanation of this fact, distinguished seven. He named the long image the spectrum, and the colours primary or elementary, as being the original simple elements of which white light is composed. They were, beginning at the bottom at R, red, orange, yellow, green, blue, indigo, and violet at V; but later observers now think that there are only three—red, yellow, and blue. In reality, however, each of these extends over the whole spectrum, but fainter in some parts; and the intermediate colours are formed by their union in various proportions, as white is by a mixture of the whole three, which may be again effected by a lens. The separate colours undergo no farther decomposition in passing through another prism, and are hence considered simple. The reason of their separation by the prism is, that the red rays are less refracted or bent from the straight line than the yellow, and these less than the blue, and therefore each of them falls on a different part of the spectrum.

This theory of the composition of light explains the cause of colour in natural objects. Some bodies reflect the whole of the light that falls upon them, others absorb part and reflect the remainder, whilst a third class absorb the whole. Such of them as reflect all the rays equally, appear white; such as reflect the red or yellow, and absorb the others, appear red or yellow; and such as reflect more than one, appear of the colour resulting from their mixture; and those that absorb all the light, appear black, or have no colour. The rainbow, the most beautiful coloured object in nature, is formed by the rays of the sun refracted and reflected from the drops of water in the atmosphere forming clouds; hence it may be seen wherever moisture is condensed in the air, as in the steam escaping from a boiler, or in the spray over a waterfall. The manner in which it is formed is shown in Fig. 55, and is a good example of the application of the principles already laid down.

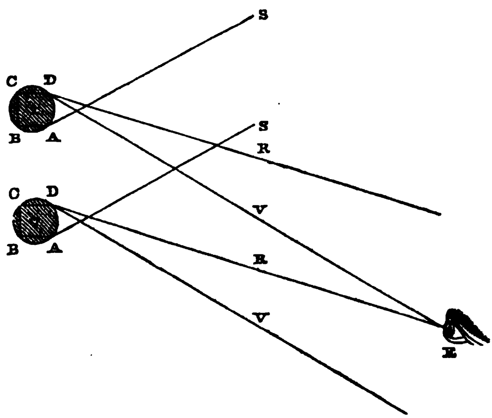
Fig. 55.



A B C (1) and (7) are drops of rain or globules of water, and S A parallel rays of light falling upon them from the sun. These rays are first refracted to B, and thence reflected to C, where they leave the drop decomposed into their constituent colours. The violet rays being the most refrangible take the highest course C V, and the red being least so, the lowest C R; the other rays being found in the intermediate space. The original rays being parallel, those formed by their decomposition are also parallel. Now the eye at E will only receive the red

rays from the upper drop (1), all the others passing above it, and only the violet rays from the lower drop (7), the remainder falling below it, whilst the intermediate colours will be received from drops placed between. Hence the various colours will be seen arranged in this order in the sky, and forming a portion of a circle or bow round the spectator. Besides this, which is named the primary bow, there is often another above with fainter colours arranged in the reverse order—the violet being the highest. In this the ray of light enters at the lower side of the drop and is twice reflected, as seen in Fig. 56, where the

Fig. 56.



letters correspond to those above. Sometimes, though very rarely, even a third still fainter rainbow has been seen.

The true nature of light is still a matter of much uncertainty. Newton conceived it to consist of very minute particles, shot forth in continuous streams, with immense velocity, from the sun and other luminous bodies. A more general theory at present is, that like sound it arises from waves or undulations of an elastic medium or ether which fills all space. Most of the facts of the science can be explained on either supposition, and neither of them is without its difficulties; but it is only an accurate knowledge of its mathematical principles that can enable any one to form an opinion on the subject.

Section VIII.—HEAT.

Notwithstanding the immense importance of heat to mankind, and the vast variety of phenomena in which it takes a part, we are still ignorant of its true nature. Some suppose it a subtile fluid pervading all bodies; others think that it is a vibratory or undulating motion in such a fluid; and others still, that it is such a motion among the particles of which bodies consist. Be this as it may, its principal effects and the manner in which it acts may be well enough explained without deciding on such a difficult matter. Heat, in common language, means either the sensation which we experience, or the cause of this sensation—the latter, in science, being often named caloric. Cold also has the same double meaning, but is now regarded as simply the want or rather the diminution of heat, as darkness is of light, and not any thing positive or actually existing by itself. Heat pervades all nature, causing the streams to flow, the plants to put forth leaves, flowers, and fruit, and all animated beings to exist. It may be doubted whether the very stones would remain what they are, if heat were absent from the universe.

The sources of the heat found on the earth are very various, though perhaps all of them are primarily one. The sun is the great natural source of heat to the earth, but how it originates in that body we cannot tell. In the interior of the earth heat is also found to exist, but opinions are much divided as to the manner in which it arises. Animal life also originates heat, which disappears when death ensues. Electrical and galvanic actions are likewise accompanied with heat. Mechanical action is also a source of heat—two pieces of wood when rubbed together taking fire, and a bar of iron growing hot by being hammered. Heat also results from chemical action; and most changes in the composition of a body occasion at the same time a change in its temperature. This is probably the true source of heat in all the above cases; and there is some change occurring at the surface of the sun and in the interior of the earth to which the heat they give out may be referred. Combustion, the common source of artificial heat, is also a chemical change, certain parts of the fuel uniting with one of the elements of the atmosphere. Animal heat is now supposed to be of exactly the same nature, a slow combustion or union of two elementary substances taking place in the lungs.

The principal effect of heat is expansion. All bodies on

being heated enlarge in their dimensions and contract when they are cooled, with the exception of water just before freezing. That solids expand may be shown by this experiment. Take an iron rod *b* (Fig. 57), which when cold just enters between the projecting ends of the bar *a*, and passes through the hole in it, and heat it, then it will be found too long and too thick to enter between the projections or pass through the hole. That fluids expand may be seen by putting the finger on the bulb of a thermometer, when the mercury as it grows warm will expand and rise in the tube. That heat expands air is shown (Fig. 58) by inverting a glass flask or bottle with a long neck, partly filled with water, in a vessel of this liquid. When the hand or any thing warm is put on the bottle, the air within will expand and press the water down in the stem. Some substances increase more than others with equal degrees of heat. Thus, when heated from the freezing to the boiling point of water, lead expands twenty-eight parts in 10,000, gold only fourteen parts, steel twelve, platina nine, and glass eight parts nearly in the same number. Fluids, on the other hand, expand far more, mercury increasing eighteen parts in 1000 by bulk, water forty-three parts, alcohol 110 parts, and oils from seventy to eighty parts. Gases expand still more when heated, a thousand measures of any of them, as common air, at the freezing point, becoming 1375 measures at the boiling point of water.

Fig. 57.

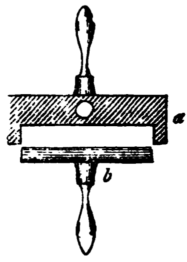
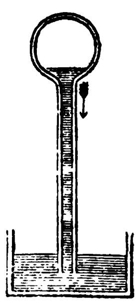
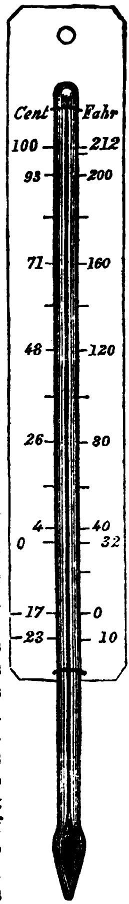


Fig. 58.



The bulk of bodies thus contracting or increasing by the loss or gain of heat, their expansion has been taken as a measure of temperature, and instruments formed for this purpose, named thermometers. There are many different contrivances of this kind, but Fig. 59 represents the most common. It is a tube of glass with a very narrow bore, expanding below into a bulb. This and part of the tube are filled with a liquid, generally either mercury or alcohol, the former being preferred for moderate temperatures. The air is mostly expelled from the upper part of the tube, which is then closed. The expansion or contraction of the liquid within is now very visible, and a scale is attached by which this may be measured. But some fixed points must be found, in order that one thermometer may be compared with another; and for this purpose the freezing

Fig. 59.



and boiling temperature of water have been chosen. In Fahrenheit's thermometer, named from the person who first constructed it, and commonly used in this country, the distance between these two points is divided into 180 parts, called degrees; and 32 similar degrees being measured off below, the numbering of the scale begins at this, named the zero point of the thermometer, 32 degrees being at the freezing point of water, and 212° at the boiling. In the centigrade division, marked on the other side of the figure, and commonly used in France, the zero, or commencement of the scale, is at the freezing point, and the distance to boiling is divided into 100 degrees. This instrument, however, only measures low temperatures, the mercury boiling at about 660°. For higher temperatures, other instruments, named pyrometers, or fire-measurers, are used. The thermometer is a very useful instrument, not only enabling us to judge of the relative temperature of different places and seasons, but being much employed in various manufactures, chiefly by chemists, brewers, and horticulturists. As an instrument of science, it is one of the most perfect and important which philosophers possess.

Water forms a singular exception to the law of general expansion by heat. Pure water, we have seen, freezes at thirty-two degrees, and, when cooling, contracts like other bodies to within about seven degrees of this point, when it begins to expand, and continues to do so till it becomes solid. At the moment of freezing it expands greatly, and thus bursts bottles or water-pipes, and is a great mean of overturning walls and breaking down rocks. This anomaly in water is supposed to arise from its particles beginning to crystallize or congeal at 39°. It is of great utility in nature, by preventing the water of rivers or lakes during frost from beginning to freeze at the bottom, where the ice on the return of summer would melt very slowly, whereas now, even when frozen above, they continue open below, and the plants and animals contained in them are preserved. Salt water does not seem to follow the same law.

We formerly noticed the structure of matter, as composed of innumerable particles held together by a force named cohesion.

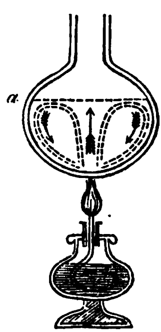
The expansion and contraction of all bodies by heat and pressure show that these particles are not in actual contact; and they must therefore be kept separate by some force which acts in opposition to the attraction of cohesion. Heat has been supposed to serve this purpose; and as attraction tends to bring the particles of matter together, so heat repels them from each other. Hence, as heat increases, bodies expand, and when it rises to a certain extent, those that are solid become liquid. This happens to different bodies at different temperatures; thus, ice, which is just solid water, melts at 32°, frozen mercury at 39° below the zero of Fahrenheit's thermometer, lead at 612° above zero, gold at 2016°, and cast-iron at 2786°. Platinum is the most infusible of the metals; and various earthy bodies, as lime and clay, are also difficult of fusion. When the heat is raised higher, the particles of bodies recede still farther, and they pass into the state of vapour or gas. Vapour from water or other liquids becomes again liquid, or condenses at the ordinary temperature; in gases this does not happen, as they then continue in the form of air. Evaporation is that process in which vapours escape, especially from water at a low temperature, and is almost constantly going on at the surface of the earth. The surface of the land, with all the animals and vegetables upon it, rivers, lakes, and particularly the sea, are constantly sending forth vapours, which ascend into the air, are condensed there, and again return to the earth and ocean, after circulating through various forms, and performing many important purposes in nature. This is the source of rain, clouds being merely the small drops of water formed from the condensed vapour of the atmosphere.

Water boils at different temperatures, according to the pressure; and hence, in forming thermometers, care must be taken that the weight of the air or the height of the barometer is the same when the boiling point is found. At Geneva, 1200 feet above the sea, water boils two and a half degrees below the common temperature; and at Quito, 9000 feet high, eighteen degrees below it. In the boilers of steam-engines, on the contrary, water is heated much beyond what can be done in an open vessel; for water when once boiling never becomes warmer, the steam carrying away all the surplus heat. Where, however, pressure prevents the steam from escaping, water may be heated to a much higher degree, and probably might even be rendered red hot. Pressure, it would also appear, can counteract the effect of heat on gases, and render them liquid at a temperature at which usually they are not so. In compressing air, however, a portion of the heat it contained seems to be expelled, and its temperature is raised, so that when suddenly compressed it will

set fire to a match. When it expands, on the other hand, air becomes cool, or part of its heat seems lost. This heat is named latent or concealed, as not showing itself by a thermometer in ordinary circumstances. This is one reason why the air on the top of mountains is colder than below, it having expanded, and therefore needing more heat in reality to give it the same warmth to the feelings or to the thermometer. Water when it passes into vapour also takes up much heat, which becomes latent, but is again given out when it returns to the liquid state. This fact is of very great importance for understanding many natural phenomena, especially the distribution of temperature on the earth.

Heat passes from one body to another in two ways. When we put our hand on a warm stone or piece of metal, we receive the heat directly by conduction or contact. When again we hold our hand opposite the fire, or in the sunbeams, we receive the warmth without touching the body whence it proceeds; and it is said to be radiated to us, or our hand is warmed by radiation of the heat from the fire or sun. In solid bodies heat is diffused in the former way, passing gradually from one part of them to another; as when the poker is put in the fire, the parts near the fire are heated sooner than those more remote. Some bodies convey heat faster than others; as the metals than wood or stone, and some metals than others. Thus, gold conveys heat nearly three times more rapidly than platinum, iron, or tin; about six times faster than lead; and ninety times more so than porcelain. Air, water, and other fluids convey heat very slowly by conduction, but the extreme mobility of their particles renders them easily warmed when heat is applied below. The warm particles then rise up in currents, and the cold heavy ones descend, till the whole mass has a uniform temperature (Fig. 60). Water, however, in a long jar or syphon may be made to boil at the upper end, when ice remains at the lower one. It is this slow transmission of heat through still air that makes clothes warm, as no currents can arise in that entangled among the fibres of the wool or cotton composing them. Hence also the superior warmth of fur and down, in which much air is thus entangled, and also the reason why in cold weather snow acts as a protection to the earth and plants.

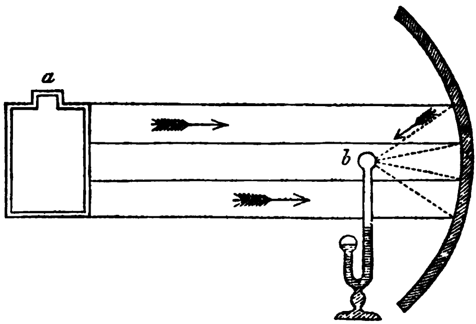
Fig. 60.



In radiation the heat passes off in rays like those of light from the sun or a candle. Like these, radiated heat diminishes in

intensity as the distance increases. It is also reflected from any polished surface, and can like light be concentrated in a point by a concave mirror, even where no light accompanies it; as in this experiment (Fig. 61), where *a* is a tin-canister filled with

Fig. 61.



warm water, *d* a concave mirror, and *b* a differential thermometer constructed so as to show small differences of temperature by the expansion of the air contained in the two bulbs. Different surfaces radiate heat in different quantities, as was shown by the above apparatus. One side of bright-polished metal radiated little heat, one of tarnished lead considerably more, one covered with paper still more, and one coated with lamp-black most of all. Hence a vessel of bright metal preserves any thing it contains warm longer than one with a tarnished or rough surface. On the other hand, a kettle when black and smoked will boil sooner than if bright and clean. Radiated heat is refracted like light in passing through a prism, and it would appear in a degree different from the rays of light, as the thermometer is affected considerably beyond the red rays, in which, however, the heating power is greatest. The common burning-glass, in which not only the sun's light but also his heat is concentrated to a focus, shows this property of heat. When collected by a large lens, or still better, by a concave mirror, very remarkable effects are produced. One of the latter four feet in diameter melted a sixpence in 7½ seconds, a half-penny in 20 seconds, and cast-iron in 16 seconds. Many natural phenomena depending on heat and its laws will be afterwards noticed.

Section IX.—ELECTRICITY.

When a piece of sealing-wax or amber (named by the Greeks *electron*, hence electricity) is rubbed on a dry woollen cloth, it will be found to attract light bodies, as small fragments of paper, straw, gold-leaf, or feathers. Substances which acquire this property by friction are named electrics, and include, besides the two mentioned, glass, resin, sulphur, the precious stones, silk, fur, and even paper when very dry. There are other bodies, named non-electrics, which cannot be thus excited, as it is called. If a thick tube of glass be rubbed, it will attract small pieces of gold-leaf, which will soon after be repelled from it, and cannot be again attracted till they have touched some other body. When rubbed in the dark, this glass cylinder will give out flashes of blueish light, and sparks will be seen passing from it in various directions. If the knuckle be held towards it, a spark will pass to it, and a sharp prickling sensation be felt.

If a globe of metal, which when in the hand could not be excited by rubbing, be suspended in the air by a silk thread, and then rubbed by an electric, as silk or fur, it will become also electric, attracting light bodies, and then repelling them. If, however, a metallic wire is used to suspend the globe, friction has no sensible effect on it. Hence it has been supposed that electricity is some property or fluid, as it is often called, which is excited in bodies by rubbing, and which is conveyed away from them by the metallic wire, whilst it cannot pass through the silk thread. The wire is therefore named a conductor of electricity, the silk a non-conductor, and bodies are divided into these two classes, which are found to be identical with the former division—all electrics being non-conductors, all non-electrics conductors. Air, when dry, is a non-conductor; and thus a body supported in it by a non-conductor is completely isolated from all other bodies, and much electricity may be accumulated in it. The tendency, however, of electricity is to diffuse itself among all surrounding bodies; and hence, when highly charged with it, a body gives off sparks to one that is brought near it, even through the air.

Electricity is of an unknown nature; but its phenomena are explained in the simplest manner, by supposing it to be an extremely subtile fluid (or, as some think, two fluids) diffused through nature. A certain amount of this is proper to each body in its natural state, but bodies are also capable of having more or less than their due quantity. In the former, they are said to have positive, in the latter negative, or if two fluids,

vitreous and resinous electricity. In conductors it moves freely, and therefore never accumulates beyond the proper amount, unless when they are isolated from all others. In non-conductors it moves slowly and with much difficulty, so that when excited it can accumulate in them, or in one part of them, in more than its due proportion. Friction does this, either if there are two fluids, by impelling one to one part of the body and the other to another; or if only one fluid, by collecting it to one part of the body. This fluid being highly elastic, its particles repel each other; and hence two bodies with the same kind of electricity repel, with opposite kinds attract each other; and hence also that tendency to spread through all surrounding bodies till each has acquired its due amount.

By means of an electrical machine, much electricity may be produced and accumulated in what are named Leyden jars, or glass bottles covered on the inside and outside with tinfoil to within a short distance of the top. Where these are large, or many of them united, a very powerful effect is produced by their discharge, the inside in which one kind of electricity is accumulated being brought into union with the outside charged with the opposite kind. The electricity may thus be made to pass through one or many individuals, who feel a shock more or less severe according to the accumulation of the fluid. It may easily be made to kill small animals, and in larger quantities even men. It exerts very great mechanical force, and in passing through pieces of wood or stone will split and tear them asunder. It also evolves much heat, and when transmitted through inflammable bodies, like gases, will set them on fire. It also melts fine iron-wire in passing through it, or, if not sufficient for this, causes it to contract. It even makes some metals volatilize, and disperses the particles of others with great violence. There are indeed few branches of science in which more singular appearances are presented than in that of electricity, or more powerful effects produced by seemingly weaker agents.

The earth and atmosphere, like other bodies, contain electricity, and many curious phenomena, especially of the latter, are explained by it. Of this nature are the Aurora Borealis, and Thunder and Lightning. The latter is supposed to be occasioned by electricity accumulating in the atmosphere till its repulsive power becomes so great that it escapes to the earth. The latter, however, seems sometimes to be most highly charged when the spark or flash rises upwards. Lightning, like electricity, is attracted by high and pointed objects, especially of metal; and hence the danger of being near such, as trees in an open field. As metals, however, are good conductors, pointed rods

are often attached to exposed buildings, for the purpose of attracting the lightning and conveying it to the ground. These are named lightning conductors, and were invented by Dr Franklin, who proved the identity of lightning with electricity by drawing it from the clouds by means of a common kite.

Galvanism is generally regarded as a peculiar form of electricity in which the fluid moves in a continuous current from one body to another. The simplest method in which it can be exhibited is by putting a piece of silver, as a half-crown, above the tongue, and a disk of zinc below it, when, on bringing the edges of the metals together, a peculiar taste and a sensation like a slight electric shock will be perceived. A similar current will be created by partly immersing two plates, one of zinc and the other of copper, in a glass vessel containing diluted sulphuric acid, and then bringing their upper edges together. Still more powerful effects are produced by increasing the number of pairs of plates, and consequently the surface of the metals exposed, and these plates have been arranged in various ways. The current thus excited gives rise to brilliant sparks and flashes of light, fuses metals, decomposes their oxides, resolves water into its primary elements, and produces many other remarkable effects. By means of this, the metal contained in a solution may be separated from it and deposited on the surface of some solid body, a process now much employed for taking impressions of coins and medals.

Section X.—MAGNETISM.

The property of attracting iron, possessed by the loadstone or magnet, was known to the ancients, but has only in recent times been turned to any useful purpose. The loadstone is found in various iron-mines, and forms natural magnets often of great power; but its peculiarities are best seen in artificial magnets, consisting of a bar of iron or steel, rendered magnetic either by touching it with a loadstone or in other ways, as by holding it inclined to the north, and striking it smartly with a hammer several times. Such a magnetic bar or magnet has various properties. Thus, it has polarity, or when suspended so as to move freely, one end always turns towards the north pole, and the other to the south. The ends are then named its poles, and that which was held lowest during the hammering points north. Either pole attracts unmagnetic iron, which adheres to it, and then also is magnetic. If two magnets, however, which can move freely are brought together, the opposite poles

only attract each other,—that is, the north pole of the one attracts the south pole of the other; whilst similar poles repel each other, or the north pole of the one flies from the north pole of the other. A magnet brought near or in contact with an iron bar, imparts its properties to it by induction, as it is called. Thus, if they touch end to end, the north pole of the magnet renders the end of the bar touching it a south pole, and the opposite one a north pole; and another bar brought into contact with the former will be affected in the same manner. A whole chain of magnets may be thus formed; but when the original one is removed, the others cease to have these properties, and no longer attract or repel each other.

The most useful application of the magnet depends on its polarity. This is the mariner's compass, in which a small bar, or needle as it is called, of magnetized steel is placed so as to move freely on a pivot in a box. This needle turns always nearly north and south, though not exactly so, deviating in this country several degrees to the west of north. This is named the variation of the compass, and is found to differ in different parts of the earth at the same time, and at the same place at different times. Thus, before 1660, the variation at London was east of north—about that year there was no variation there; then it became west, and increased to 24½° in 1818, and is now again decreasing, or moving east—the line of no variation, or where the compass points due north and south, now passing through America. The variation also changes slightly during the day; and these diurnal variations are greater in summer than in winter, whence they are thought to be connected with the sun's heat acting on the earth. When a needle is properly balanced before being magnetized, after it has acquired this property its north pole is found to be inclined, or to dip down from the horizontal position. This, termed the dip of the needle, varies in different places, and at London is about 70°. At the magnetic pole, in North America, the needle dips vertically, and consequently can no longer point out the direction.

Many facts show that magnetism and electricity are closely connected, if not different forms of one power. Thus, magnetism can be excited in iron by electricity; and some very powerful magnets are thus formed, capable of supporting hundreds or even thousands of pounds weight. Sparks have even been drawn from powerful magnets. By striking a ship, lightning has also been found to affect the compass, sometimes depriving it altogether of polarity, at other times reversing its poles. The connexion of these agents now forms a peculiar branch of science, named Electro-Magnetism.

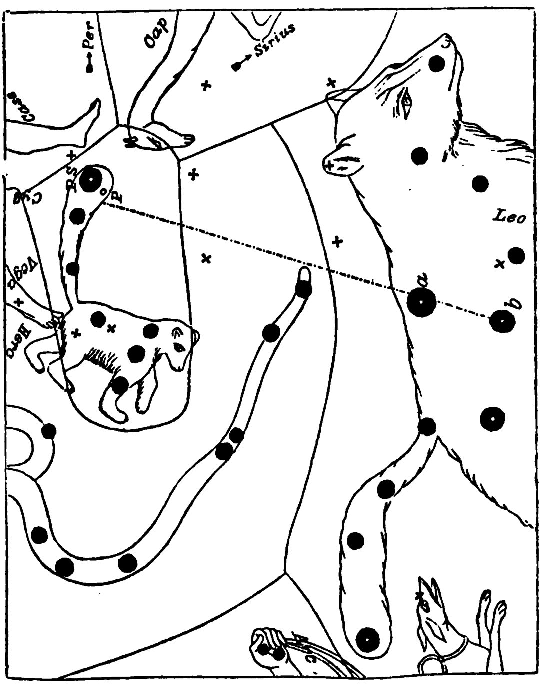
Section XI.—ASTRONOMY.

This science is named from two Greek words which mean the law of the stars, and treats of the appearances and relations of the heavenly bodies, and the laws which regulate their various motions. The common division of these, according to their apparent importance as seen from the earth, is into sun, moon, and stars; but more accurate notions, derived from long observation, show that they may be better classed as stars, planets, satellites, and comets. Among the numerous stars that in a clear night appear in the sky, some are found to retain always the same position in relation to each other, and to be seen from night to night arranged in groups of unvarying forms. These are therefore named fixed stars, to distinguish them from a few whose place relatively to the others is continually and sensibly changing, and which seeming thus to *wander* through the sky, were named planets by the Greeks, from a word having that meaning. The sudden changes in the refractive power of the air causes the fixed stars to twinkle, while the planets shine with a steady light, from having greater apparent size. Upwards of 150,000 stars have been registered; but only about two thousand can be seen in the heavens by the naked eye, and these are all fixed, except five, the number of the planets which are visible. With a telescope, however, their numbers increase beyond calculation, and Sir William Herschel reckoned that the mere motion of the heavens caused 50,000 to pass in one hour through the field of his telescope. This instrument is now supposed to bring upwards of a hundred millions of these luminous bodies into view, which without it would have remained for ever hid from our vision.

Not less wonderful is the immense distance of these bodies from that part of the heavens where our earth is situated. With the most powerful telescope they have no visible size, but remain mere points of light, of various degrees of brightness. As they do not alter their position sensibly when seen from the earth in opposite points of her orbit, distant 190 millions of miles from each other, they must therefore be more than a hundred thousand times that distance, or so far that light moving at nearly 200,000 miles in a second takes more than three years to reach the earth from them. It has been calculated of one, supposed to be among the nearest to our planet, that it must be at least twice this distance, or so far that its light would take six years to reach the earth. As they appear of different degrees of brightness, and we have no reason to suppose that those near us are

brighter than the more remote, some of those that are scarcely visible must be removed to enormous distances. Thus, Sirius, the dog-star, one of the brightest known, gives 324 times more light than a star of the sixth magnitude, which is just invisible to the unaided eye, and therefore must be fifty-seven times nearer to us, if both have in reality the same brightness; or nearly two hundred years must elapse before the light which has left the latter can reach our earth; and yet there are many others far less brilliant, and probably more remote. The distance of Sirius may be conceived from the fact, that its light is twenty million of million times less intense than that of the sun; and yet it is calculated that were it situated where the sun is, it would appear at least more than 3½ times as large, and give nearly fourteen times as much light.

Fig. 62.

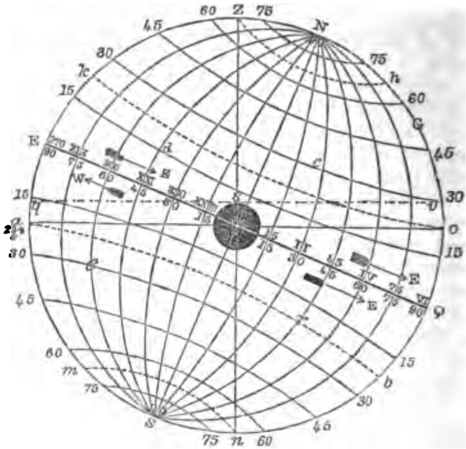


The stars have been classed according to their apparent brightness, or magnitude as it is named. Those of the fifth magnitude are hardly discernible by the unaided eye, and those of lower magnitudes not without the assistance of telescopes. Only eighteen or twenty stars are of the first magnitude, and about 250 of the first three magnitudes; so that the number of bright stars is not great. The stars also form groups in the heavens, which are called constellations, and named from their fancied resemblance to various natural objects. Thus, in Fig. 62, the principal stars near the north pole are seen as arranged in constellations; one of which, the Little Bear, or Ursa Minor, as it is usually named, is wholly included in the figure. The bright star P S, at the tip of the tail, is named the pole-star, from its close approach to the true north, which is at P. This star is of the second magnitude, and is easily found by the seven well-known stars forming part of the Great Bear, seen at the foot of the figure, and commonly named the Plough, or Charles' Wain. A straight line joining two of these (*b a* in the figure), named the pointers, passes very close to the pole-star, which has no very bright ones near it. From these, by means of a globe, or "maps of the stars," the other constellations and remarkable stars may be found. Thus, in the above figure, a line from the pole-star, in the direction of the letters *Herc*, would pass through the constellation Hercules; through *Vega* to that star; and so on successively to *Cygnus, Cassiopeia, Perseus, Capella, Sirius, Leo,* and *Arcturus.* The use of these constellations is to enable astronomers to recognise the various stars in the heavens, those in each being named by the letters of the Greek and other alphabets, or, when these are not sufficient, by numbers.

The surface of the heavens, as seen by us, may be represented by a hollow sphere, on which the position of the stars is fixed by their relation to certain known points and lines. This is seen in Fig. 63, where the small black globe represents the earth, surrounded by the various imaginary lines supposed to be drawn on the sphere of the heavens. Here, N and S are the north and south poles, E Q is the equator, and the other circles above and below it are termed parallels of declination. These are divided into twenty-four equal parts by hour-circles, the distance between each being the space passed over by the sun in that time, or fifteen degrees. The line *a o* is named the ecliptic, and marks the path on the heavens described by the sun in his annual motion; and the points where this cuts the equator are named the equinoxes, marking the position of the sun at those seasons when the day and night are equal. The zenith is the point of the heavens directly over the spectator on the earth, as

Z to a person placed at S; the nadir *n* is the opposite point directly below him.

Fig. 63.



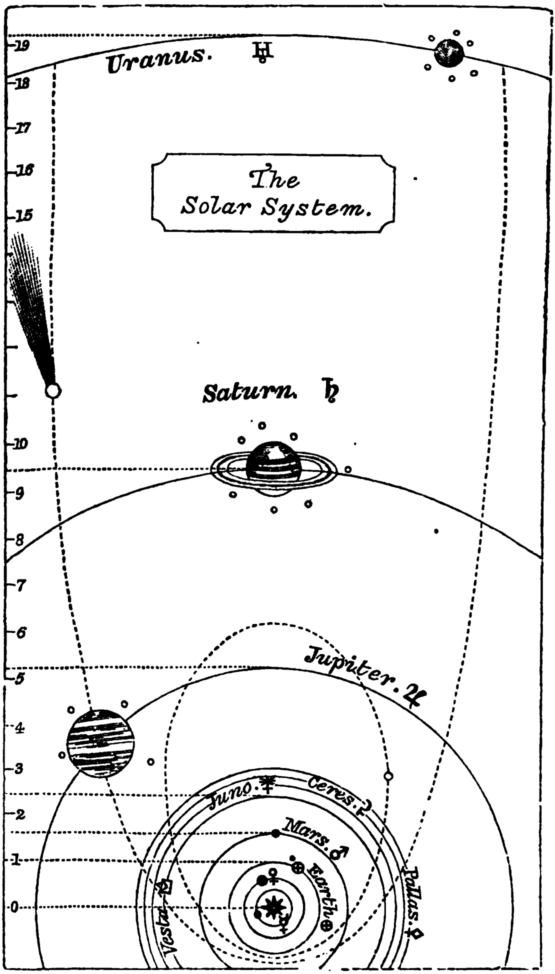
There are other differences among these fixed stars which show that this name is not always strictly true. Thus, some stars have appeared suddenly in the heavens, and as suddenly disappeared; like one which, in 1574, was discovered in Cassiopeia, and rapidly increased in brightness till it surpassed Jupiter in splendour, and then diminished till it vanished after sixteen months. It is supposed to be periodical, and to have been that formerly seen in 945 and 1264, at intervals of about 300 years. Other stars are named variable, from alternately increasing and diminishing in magnitude, as Algol, in the constellation Perseus, which for two days and fourteen hours is a star of the second class; but then beginning to decrease, is reduced to one of the fourth magnitude in 3½ hours, and in the same period regains its usual magnitude. This is supposed to be owing to the revolution of some opaque body round it, which for a time intercepts its light. Others vanish altogether for a time, and then reappear, but in such a manner as to prevent even a conjecture of the cause.

Some stars that seem but simple shining points to the eye, can by the telescope be resolved into two or more. These are named double stars, and some thousands of them are now known;

one, in Orion, consisting of no less than five stars, one of which is variable. These form systems revolving round each other in periods of various duration, extending among those which are known from 43 to 1600 years. Though to us therefore apparently fixed, they are in constant motion, with a velocity which, in one case, has been calculated at upwards of 100 million of million miles annually; and yet it takes 452 years to complete its revolution. Such vast rapidity, combined with such enormous periods of time, can scarcely be conceived by the human mind, and must impress every one with a sense of his own weakness and insignificancy. These double stars are, however, found to follow the same laws of motion which regulate the orbits of the planets; and thus prove that one uniform system prevails, and that one all-directing Mind has formed the mighty universe. This is especially manifest in the clusters of fixed stars observed in various parts of the heavens—as, for example, the Pleiades—it being mathematically demonstrable, that there are 500,000 chances to one against these stars having come into their present limited space by mere accident; and the probability is still greater against this being the case with the double, triple, and quadruple stars. These double stars are of various and often contrasted colours—the large star being generally yellow, orange, or red, and the small one blue, purple, or green. A white star is also sometimes seen associated with a blue or purple, and more rarely with a red star. The cause of these differences of colour in the heavenly bodies is unknown.

Nebulæ are still more remarkable objects, appearing to the naked eye like thin white clouds, or irregular spots of pale light scattered over the heavens. The milky-way is one of the most extensive and best known of these, but with a powerful telescope is resolved into an infinite multitude of minute stars. It seems to form a vast layer or stratum of these, of great extent compared to its thickness, the sun and the most brilliant fixed stars forming part of it. Other similar clusters, composed of thousands of orbs, are seen in various other parts of the heavens, forming as it were societies or groups by themselves. Some of these cannot be resolved into stars, and Herschel conceives that this is not caused merely by their enormous distance, but that in reality they consist of a luminous matter diffused through space, and gradually collecting and condensing into suns and systems similar to our own. Their number is very great, Sir John Herschel having already given the places of 2500; but few are visible to the unassisted eye, and in our cloudy climate only, on an average, during about thirty nights in the year.

Fig. 64.



19
18
17
16
15
10
9
8
7
6
5
4
3
2
1
0
Uranus. ♅
The Solar System.
Saturn. ♄
Jupiter. ♃
Juno.
Ceres.
Mars. ♂
Earth ⊕
Vesta
Pallas.

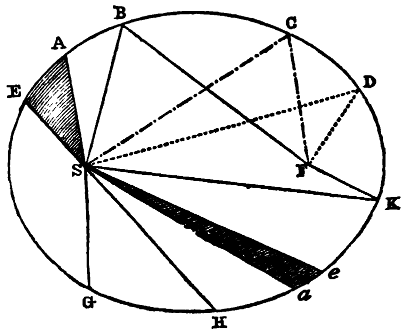
The Solar System.

The sun, then, is one of these stars, owing its apparent magnitude to its smaller distance from us. The planets, including the earth, are connected with the sun by fixed laws, and with it compose a system by themselves, which, however vast it may seem to our imaginations, is almost as nothing compared to those groups of suns we have been considering. The solar system is exhibited in Fig. 64, where the planets have their true sizes in relation to each other, though not to the sun, which if represented in proportionate magnitude, would have extended almost to the satellites of Saturn. Their relative distances from the sun's centre are also exhibited. The system is thus seen to consist of the sun in the centre, and eleven planets, with their satellites, in the following order:—Mercury, Venus, the Earth with her satellite the Moon, Mars, Vesta, Juno, Ceres, Pallas, Jupiter with four moons or satellites, Saturn with two rings and seven satellites, and Uranus with six satellites; in all, thirty-two distinct bodies; to which the comets, in unknown numbers, would require to be added, in order to complete the whole.

The central body, the sun, is ninety-five million miles from the earth, and nearly 112 times its diameter, so that its bulk is 1,384,472 (or more than one million and a third) times, and its weight nearly 355 thousand times that of the earth. It seems to be an immense globe, surrounded by a dense luminous atmosphere, like an ocean of flame, through openings in which the dark central nucleus sometimes appears, forming what are named solar spots. These are found principally near his equator; and as they are seen to appear on one side and vanish on the other, it is hence supposed that the sun turns on his axis like the earth, and in the same direction, in a period of twenty-five days and ten hours. The light and heat, however they may originate, are supposed to be produced in this atmosphere, and some appearances have been supposed to show that there is an inferior atmosphere, not luminous, between this and the body of the sun. In consequence of his rotation, the sun is not a perfect sphere, but his equatorial diameter is about a thirteenth part more than the polar. He is supposed to move slowly through space towards the constellation Hercules, but this is not certain. His other motions are only apparent, arising from those of the earth.

The planets revolve round the sun in tracks named orbits, which, with a few slight deviations, are ellipses or oval figures. The most important points in the orbit (Fig. 65) are S and F, named the foci, so placed that a thread held fast at them, and uniformly stretched, would pass over the outline of the figure, as

Fig. 65.

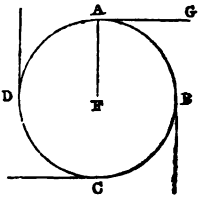


S C F, or S D F. The sun is situated in one of the foci as S, and a line from it to the circumference, where the planet is moving, is named the radius vector. The first law concerning the motion of the planets therefore is, that they move in ellipses, of which the sun is in one of the foci. The second of these laws is, that the radius vector of a planet describes areas proportional to the times, or equal areas in equal times. This will be better seen in the figure, where, if E A is the space passed over by the planet in one part of its orbit in a certain portion of time, and *e a* also the space passed over in another part in an equal portion of time, then the areas described by the radius vector, shaded black in the figure, will be equal. Hence it follows that the planets must move most rapidly when nearest the sun, or in the perihelion, and slowest when most distant, or in the aphelion. The time a planet takes to move round its orbit is named its periodic time; and the third law is, that the squares of the periodic times of the planets are proportional to the cubes of their distances from the sun. Thus, Mars is about four times farther from the sun than Mercury, and its time of revolution about eight times that of the latter; and the cube of four or sixty-four is the same with the square of eight. These three laws, first observed by Kepler, commonly go by his name, and are found to prevail throughout the whole solar system.

The planets have two proper motions,—one by which they turn on their axes, or that of rotation; and another of revolution, in consequence of which they revolve round the sun. The former, as in the case of the sun, causes their form to be not exactly spherical, but compressed at the poles, and bulging out round the equator. The force producing the revolving motion would, if acting alone, cause the planet to fly off in a straight

line, as A G (Fig. 66), unless retained by some force drawing it towards F, the centre of the system, or the sun in the case of the planets. The former force is named the projectile, as that by which the planet has been projected on its path in space, and the centrifugal, as tending to make it fly away from the centre. The latter is attraction, which we have already seen causing a stone to fall to the earth, and which acting on all the bodies in the universe has a tendency to bring them together, and as drawing the planets to the sun, the centre of the system, is named a centripetal force. It is the great discovery of Newton to have demonstrated, that the planets are retained in their orbits by the same force which draws an apple to the ground, and that this force is regulated by a simple law. Every particle of matter attracting every other, the force of attraction, or gravitation, as it is sometimes named, must increase or diminish with the number of these,—that is, with the mass of the body. But, like all forces spreading from a centre, it must diminish with the distance; and this in the same manner as light or heat. These two facts combined give the general law of gravitation, which is, that its force is directly as the mass of the bodies, and inversely as the square of their distance. It must also be kept in mind, that, action and reaction being equal, while the sun attracts the planets, so likewise must the planets attract the sun, only their mass being comparatively insignificant, the effect they produce on it is nearly imperceptible, and the centre of gravity round which the system revolves differs little from the sun's centre.

Fig. 66.



Mercury, the nearest of the planets, is thirty-seven million miles from the sun, round which it revolves, in a rather more than usually elliptic orbit, in about 88 days. Previously to the discovery of the asteroids, it was the smallest planet known, being 3174 miles in diameter, and turns on its axis in 24 hours 5 minutes. It is always very near the sun, and consequently seldom visible to the naked eye, and that only for a short time after the setting or before the rising of the sun. Some mountains in Mercury are estimated to be eleven miles high. It presents phases like those of the moon, when seen through a telescope. From Mercury, the sun will appear three times as large as to us, and impart seven times as much light and heat.

Venus, the evening and morning star, and the most splendent of the planets, is also between the earth and the sun, being about sixty-nine million miles from the latter. Its diameter is 7727 miles, the time of rotation 23 hours 21 minutes, and of

revolution 224 days 16 hours and 49 minutes. As well as the former, it is sometimes seen to pass between the earth and the sun, moving like a black spot over his disc. This is named a transit, and happens very rarely, the orbit of this planet being much inclined to that of the earth, or the ecliptic. It was to observe one of these transits of Venus, in 1769, that Cook undertook his voyage to the South Sea, it not being visible on this side of the earth.

The globe we inhabit, or the earth, comes next in order. Its mean distance from the sun is ninety-five million of miles, though sometimes $2\frac{1}{2}$ millions more or less; being nearest the sun in the end of December, and in the beginning of July farthest from him. Its mean diameter is 7912 miles; its time of rotation, or the true sidereal day, is 23 hours 56 minutes 4·09 seconds, being thus somewhat shorter than our mean solar day of 24 hours. The time of the earth's revolution, or the common year, is 365 days 5 hours 48 minutes and 49·7 seconds, or about 20 minutes less than the sidereal year. The earth is accompanied by the moon, a satellite or secondary planet, having a diameter of 2160 miles, and distant 237,000 from the earth, or about sixty times the earth's semi-diameter. The moon turns on her axis in 27 days 7 hours and 43 minutes, and also revolving round the earth in the same time, always presents nearly the same side to us. We shall afterwards notice some other phenomena of these two bodies.

Mars is the first of the *superior* planets, as those farther from the sun than the earth are named. It is distant one hundred and forty-four and a half million miles from the central luminary; has a diameter of 4100 miles, or rather more than half that of the earth; rotates on its axis in 24 hours 40 minutes, and revolves round the sun in 686 days 23 hours. This planet has a dull red colour, whence probably the name, and when near the earth appears pretty large and bright, though much less so than Venus or Jupiter. It exhibits phases, though only like those of the moon near the full, never showing so little as the semicircle illuminated. Mars is thought to have a considerable atmosphere, and the greater brilliancy of the parts near the poles has been ascribed to an accumulation of ice or snow there. Yet the sun's influence being only a half of what it is on the earth, water will not remain fluid on any part of its surface, and even quicksilver will be frozen in the temperate zone.

Beyond this are four small planets or asteroids, named Vesta, Juno, Ceres, and Pallas, situated from 223 to 262 million miles from the sun. They are supposed to be fragments of a large planet broken in pieces during some convulsion. Their orbit is more inclined to the ecliptic than that of any other planet; they

are much smaller than any of the others, and they are more nearly at the same distance from the sun. Ceres and Pallas have very extensive atmospheres, whereas Vesta does not exhibit any traces of one. They are not visible with the naked eye, and their true size is far from being well ascertained.

Jupiter is the largest and often the brightest of the planets, notwithstanding his remote position. He is four hundred and ninety-three million miles from the sun, round which he takes nearly twelve years to revolve. His equatorial diameter is eighty-six thousand miles, or about eleven times that of the earth, and his polar axis is a fourteenth part, or 6000 miles less. This arises from the shortness of his time of rotation, only ten hours, so that his equator is moving seven and a half miles in a second. The surface is marked by numerous darker-coloured zones or belts parallel to the equator, and also by several spots. He seems to have very little atmosphere, and the temperature must be still lower than at Mars. Though so much larger than the earth, yet his mass is surpassed by that of the sun 1048 times. Jupiter is accompanied by four satellites or moons, first seen by Galileo after the discovery of the telescope. They are rather larger than our moon, and like it revolve round their primary from west to east in various times, which are also those of their rotation on their axes. Their eclipses are of great use in practical astronomy, and for determining the longitude. They also furnished the means of measuring the velocity of light, being found to happen too soon when Jupiter was nearest the earth, and too late when he was farthest from it. The difference was 16 minutes 26 seconds; and the distance in the one case 190 million miles more than in the other; and hence light must travel about 192,000 miles in a second. In consequence of this the appearances of the heavens are not seen by us at the time they happen, but after a greater or less interval.

Saturn is still more remote, and shines with a less brilliant light. It is nine hundred and four million miles from the sun, and takes about twenty-nine and a half years to perform a revolution round it. Its greatest diameter is about 79,000 miles, its smallest 7000 less, and its time of rotation 10 hours 16 minutes. This planet has seven satellites—the most remote 2½ million miles from it, and thought to be larger than Mercury. The most remarkable phenomenon connected with this planet, however, is the two rings by which it is surrounded. These are not above a hundred miles thick, yet the inner one is 17,000, and the outer above 10,000 miles broad, with an interval of 1790 miles between them. They revolve in a few minutes more than the time of the planet's rotation; but their use, unless to reflect light to the planet, is wholly unknown. Saturn enjoys only a ninetieth

part of the light and heat from the sun which the earth receives.

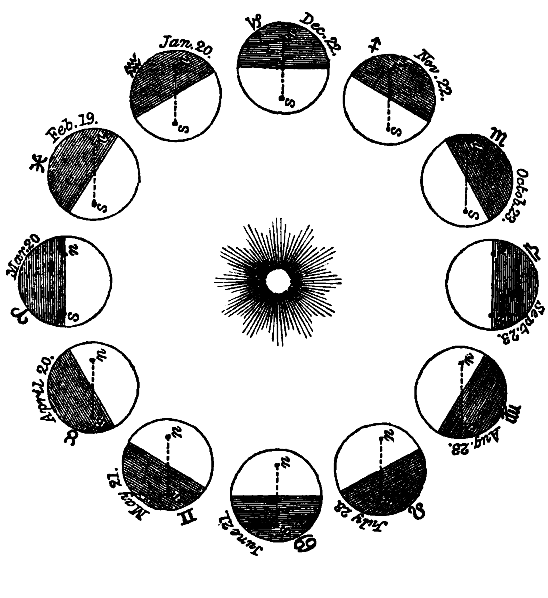
Uranus is the most distant of the planets, being more than nineteen times farther from the sun than the earth, or 1819 million of miles. It is about 35,000 miles in diameter, and revolves round the sun in eighty-four years, deriving from him only a 366th part of the light and heat experienced at the earth. It is attended by six satellites, which move in orbits nearly perpendicular to that of the ecliptic, and, unlike the others, rather in a direction from east to west, if these terms can be applied. Its discoverer, Sir William Herschel, supposed it also to have two rings at right angles to each other, but this as yet is uncertain.

Comets, though many of them only visit the known part of the solar system after long intervals, seem yet properly to belong to it, and some are known to revolve round the sun in fixed periods, and never to pass beyond the orbit of the planets. They are named from the appearance of their tail, which the ancients compared to a bunch of hair. The tail, however, is not found in all of them, many presenting merely a bright nucleus, surrounded by a zone of paler light, which, when spread out on one side, constitutes the tail; whilst others resemble a mere faint nebulous mass, only distinguished from true nebulæ by its motion. The physical constitution of comets is little known, and they seem to consist principally of a mass of vapour, the central and brightest part of which is named the nucleus. Even the smallest stars may, however, be seen through this vapour, and their solid parts, if any, have no sensible diameter. Round this are various hollow envelopes like clouds, raised up by the heat of the sun, which, on the side opposite to him, are prolonged into a hollow cone, forming the tail. This is often of enormous length—that of the one in 1811 being no less than 100 million of miles long, but of such tenuity that the smallest stars were seen through it without refraction. The orbits of comets are much elongated, in one part approaching very near to the sun, and in the other retiring almost beyond his influence. Some comets are known to return at regular intervals, as that of Halley, in seventy-five or seventy-six years; but its later appearances are far inferior in splendour to the earlier ones, since in 1456 it excited great alarm, whereas in 1835 it was by no means remarkable. Biela's comet revolves in $6\frac{3}{4}$ years, never passing beyond the orbit of Jupiter, whilst Halley's wanders to twice the distance of the orbit of Uranus. Encke's comet has a period of only $3\frac{1}{3}$ years, or 1207 days, which, as well as that of Biela's, is gradually shortening. From this, and from the direction of the tails of other comets, it is believed that space is filled by a thin ether, in passing through which their progress is impeded. Their numbers seem very great, 140 which

have not been seen again, having appeared during the last century. It is computed that there may be ten times as many which in part of their course pass within the earth's orbit, whilst those which come within the known limits of the solar system are estimated at from seven to eleven millions. Most of them, on account of their distance from the sun and the earth, are and must continue invisible; and the fears of any danger from their coming in contact with the globe we inhabit, are now known to be as unfounded as the influence formerly ascribed to them over human affairs and the destiny of nations.

Perhaps the most interesting astronomical phenomena are those that concern our own earth. By turning on its axis, and thus successively presenting every part of its surface to the sun, it causes day and night. Were the sun always vertical over the equator, or middle circle of the earth, the day and night would have the same length over the whole globe throughout the year, and there would be no change of seasons. But in moving in her annual course round the sun, the earth's axis always remains parallel to itself, and thus various parts of its surface come to be more directly exposed to the light of the sun, as will be understood from Fig. 67, representing in an irregular way the position

Fig. 67.

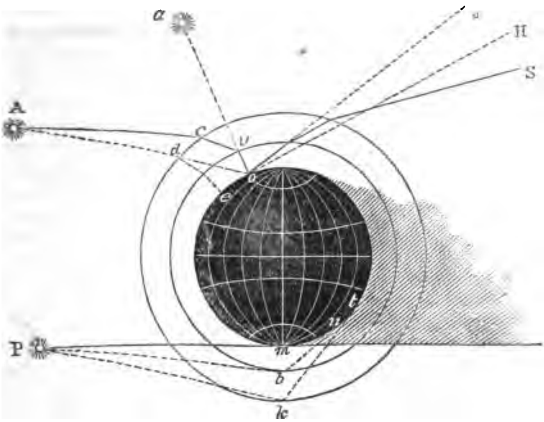


of the earth's axis relatively to the sun at different periods of the year, *n* and *s* being the north and south poles. It must, however, be understood that the earth's axis is not in the plane of its orbit, which may be represented by the surface of the paper, but as if raised up on the one side and sunk below it on the other, at an angle of 66½°. This explains both the different lengths of the days, and the cause of the seasons. When the north pole is most turned to the sun, then the day in the northern regions is longest and the heat most intense, both from the sun being longer visible, and from his rays falling more directly on the earth. The south pole to a distance of 23½° is then shrouded in darkness, and at the pole itself the night continues for six months. In our winter the case is reversed, the south pole being then turned to the sun, and the north involved in cold and darkness.

Day and night do not, however, succeed each other suddenly, but, by a wise arrangement, the one gradually fades away into the other. This arises from the air not being perfectly transparent, so that in passing through it the sun's rays are partly intercepted, partly reflected, partly refracted, in the manner explained in Optics. Hence both the light and heat become weaker as he descends to the horizon, but at the same time continue after he is below it. Refraction causes the sun to rise sooner and set later than he would otherwise do, and also shortens the period of prolonged darkness at the poles. The particles of air also reflect a portion of the light that falls upon them, which is thus transmitted to the earth long after the sun has sunk below the horizon; so that during summer in our climate there is no total darkness, but the evening twilight meets with that preceding the rising of the sun. The reflection of light from the air is of vast importance in another way, as it is thus diffused over all nature, and objects are illuminated and rendered visible on which the sun does not directly shine. Without this we should either have been blinded by his direct rays, or left in complete darkness. The manner in which refraction acts on the rays of light during their passage through the various strata of the air is shown by the lines in the upper part of Fig. 68, a star at A or S appearing as if at *a* or *s*, the ray from the former being refracted at *c* and *v*. Reflection, tending to produce twilight, is shown by the lines in the lower portion, where the light from the sun at P is reflected at *b* and *k* to the dark part of the earth at *n* and *t*.

The moon, though so small compared to the planets, and still more so to the sun, yet from her proximity to the earth affects it more powerfully in some respects than either. Her diameter is 2160 miles, or rather more than a fourth of that of the earth, and her mass only an eightieth part of that of our planet.

Fig. 68.

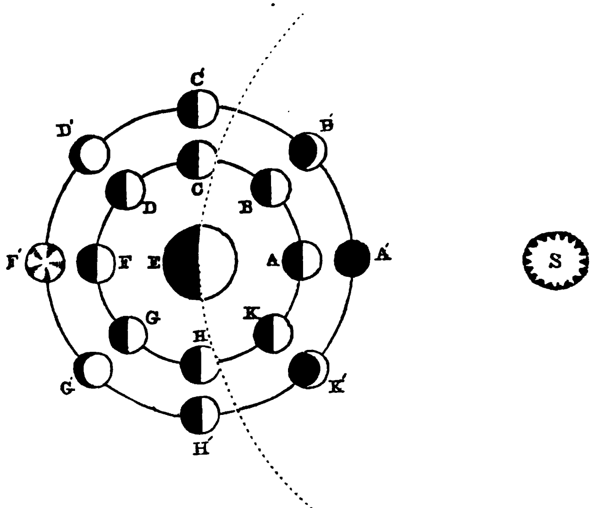


Turning on her axis in a sidereal month, her day must be equal to 29½ of ours, and her surface be alternately exposed to nearly fifteen days of sunlight and darkness. Hence, unless some compensation exists, extreme diversity of climate must prevail in the same place during the day and the night. The moon seems also to have no atmosphere, or one far less dense than that of the earth; and therefore it is supposed that no fluids like those known to us exist there. The surface, as seen through a good telescope, exhibits numerous mountains, generally of a circular form, perfectly resembling volcanoes, to which they exhibit a similarity in other respects. These are known by their shadows when near the limits of the illuminated part, and their height has thus been calculated as in some cases upwards of a mile and a half; so that their summits in the dark part of the moon are often illuminated by the sun's rays long before these have reached the valleys between them.

The changes of the moon, or her phases, as they are called, during which she gradually increases from a mere line of light to a full round orb, and again diminishes, are thus occasioned. The moon has no light of her own, but shines merely by that of the sun reflected from her surface. Hence only that side turned to the sun is enlightened and can be seen by us. But, owing to her motion round the earth, more or less of this illuminated portion is turned to us at different times, so that she

has all varieties of magnitude. This is shown in Fig. 69, where S is the sun, E the earth, the inner circle of globes A B C, &c., the moon as enlightened by the sun, and the outer circle A′ B′ C′, &c., its appearance as seen from the earth. At A,

Fig. 69.



or new moon, she presents her dark side only to the earth, and therefore is wholly invisible; whilst at F, the light side being then turned to the earth, she is seen full, and at intermediate points partly light, partly dark.

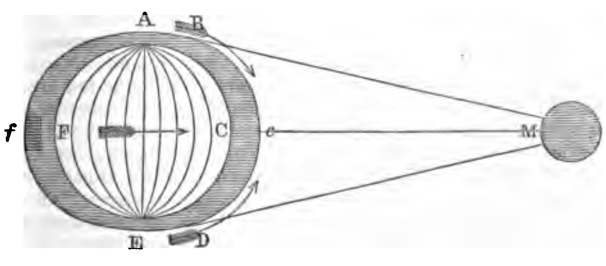
This figure will also explain the cause of eclipses of the sun and moon. Did these and the earth move in one plane, like the paper they are figured on, then whenever the moon came into the position A it would obscure the sun from a portion of the earth, and there would be an eclipse, as it is named, of the sun; on the other hand, when it came to F, then the earth would interpose between it and the sun, and there would be an eclipse of the moon. But the moon's orbit being inclined 5° to that of the earth, this obscuration of one body by the other seldom takes place. On some occasions the three bodies are not exactly in one straight line, and only part of the sun or moon is obscured, forming a partial eclipse. The moon also being much smaller than the sun, only hides the whole of it when very near the

earth; at other times, though passing directly over the centre of the sun, she only covers the central part, and appears like a black spot in the midst of a ring of light, forming what is named an annular eclipse. A total eclipse takes place when the sun is wholly hidden from us by the moon, or when the moon is completely involved in the shadow of the earth.

All the appearances which the moon presents to us, our globe must present to an inhabitant of the moon; only the earth will appear above thirteen times larger, and therefore give so much more light. The phenomenon of the old moon in the new one's arms, as it is named, arises from this reflected light, which renders the obscure part visible to us. It is only seen in the end of the last or beginning of the first quarter, or near A in the above figure, when the light part is small, and the bright face of the earth is turned fully towards it. The moon eclipses other stars and planets; but these, when she hides them completely, are named occultations. Where a planet passes between us and the sun, it is named a transit, its size not being sufficient to produce an eclipse or sensible diminution of light.

Every one who lives near the shore of the ocean is familiar with the tides, in which the water gradually rises and falls twice in about every twenty-four hours (24 hours 50 minutes). Their connexion with the motions of the moon and sun, especially the former, have been long ascertained. The moon has most influence, and her action is shown in Fig. 70, where M is the moon, and F C the earth surrounded by the waters of the ocean.

Fig. 70.



The moon attracts every portion of the mass of the earth in proportion to its nearness, and hence the water at *c* is attracted more than the solid earth F C, and is thus raised: in like manner, the earth is attracted more than the water at *f*, which is left behind. Hence the ocean at these two points is elevated, and being drawn away from A and E, there is high water at the two

former, low water at the two latter. The earth turning successively round, the tides follow the position of the moon; only, owing to their inertia, the highest part is not directly under it, as in the figure, but considerably behind, or to the eastward. The sun, in like manner, produces a tide, but less than that of the moon. When the two unite their influence, which happens when the three bodies are in one straight line, or at new and full moon, the rise is highest, or there is a spring-tide; when the sun is at right angles to the moon, or in the quarters opposite to A or E, then they oppose each other, and there is neap-tide, with the smallest rise of water. The ocean being, however, broken up by the land, the tides are very irregular, and their height various. On the shores of the South Sea Islands the rise is only one or two feet, whilst on the coasts of Europe and Asia it is in some places forty or fifty. From the motion of the tides it has been conjectured that the mean depth of the Pacific Ocean is about four miles, and that of the Atlantic three.

The motions of the heavenly bodies form the natural measures of time, whose primary divisions are the day and year from the motions of the earth, or apparently of the sun, and the month from those of the moon. The solar day, measured by the return of the sun to the meridian, varies in length at different seasons, but in civil life the mean of these is taken and divided into twenty-four hours. The difference of the mean from the true solar time is named the "equation of time," and sometimes amounts to sixteen minutes. The sidereal day, or the time a star takes to return to the same meridian, is always uniform, and about four minutes less than the civil day. The year is not an exact number of days, but $365^{d.}\ 5^{h.}\ 48^{m.}\ 49{\cdot}7^{s.}$, and therefore the civil year, consisting of whole days, does not agree with the natural year. To remedy this, leap year was introduced in the time of Julius Cæsar, an additional day being added to the month of February every fourth year. This is, however, too much; and Pope Gregory found that in his time the overplus amounted to eleven days, which, to restore the equinoxes to their former time, he suppressed in the year 1582, thus giving rise to the distinction of old and new style; the latter of which is now twelve days before the other. By the present arrangement, the calendar never varies a day from the true year, and the error still left will only amount to a day after about 4000 years. The month, originally counted from new moon to new moon, would consist of about 29½ days, the period of a synodic revolution of the moon, but now, as is well known, varies from 28 to 31 days, with no reference to the changes of the moon.

Section XII.—CHEMISTRY.

This science has a closer affinity with those we have been lately considering than might at first appear. Both treat of the laws of relation and of motion, or of attraction and repulsion, in material bodies, and of the changes which they undergo in conformity to these laws. The principal distinction is, that the mechanical sciences in general treat of the phenomena of masses of matter of visible magnitude and at sensible distances; chemistry of those of invisible atoms at distances too minute to be discerned by our faculties. Some sciences, as those which treat of the motions of fluids, seem to form an exception to this; but in these the particles, as those of air, water, or quicksilver, are all of the same nature, whereas in chemistry the atoms are of a different nature from each other. Some phenomena, as those of heat and electricity, seem to belong equally to both departments, and the connexion between the two is every day becoming more evident. It is indeed far from improbable that the primary law of attraction and repulsion will be found to be the same in both branches of science, and chemical facts become equally matters of calculation with those of mechanics.

Most bodies existing in nature are found to be not only composed of various atoms of one kind, but also of atoms of different kinds, which, by certain processes, may be separated from each other and exhibited each by itself. The manner of performing this is named analysis, and the bodies which cannot be further analysed, or divided into simpler substances, are named elementary bodies or simple substances. The object of chemistry is to make known these elementary substances, their relations to each other, the various compounds which they form, the laws according to which they combine, and the changes which they undergo in various circumstances. It thus would lead to an examination of all the bodies existing on this earth; and till this is accomplished, the science cannot be considered as complete. The composition of the various bodies composing the animal, vegetable, and mineral kingdoms, with the laws which regulate their increase or dissolution, thus form important branches of chemistry. Here, however, only a few of the more general principles, with the most important elements and their compounds, can be noticed.

Bodies, as formerly mentioned, consist of innumerable particles held together by what is named the attraction of cohesion. These particles in the same body are all of a uniform nature, as those composing a piece of wood, metal, or stone. Chemical

attraction or affinity, on the other hand, acts on particles of different natures, causing some to combine, whilst others will not do so. A simple example of this is water, which combines readily with sugar or salt, but when mixed with oil, soon separates from it. The lowest degree of this combination is named mixture, which only takes place between fluids or solids when reduced to the fluid state by heat. Thus water and alcohol form a mixture which does not separate like that of water and oil. The atmosphere or air we breathe is also considered as a mixture of at least two gases or kinds of air, as shall be afterwards noticed. Some liquids when mixed together contract; thus, a measure of sulphuric acid or alcohol, when mixed with an equal one of water, does not quite fill the two measures. When merely mixed, neither of the bodies loses its essential properties, but the mixture partakes of those of both.

Solution is the union of solid or aerial bodies with a liquid in which they are dissolved. A good example of this is a piece of sugar placed in water, in which we see it gradually dissolving till it disappears. All solids, however, cannot be thus dissolved, a piece of wood or metal remaining unchanged in water. Other fluids can dissolve many bodies on which water has no effect. Thus, sulphuric acid, or oil of vitriol, dissolves metals and stones, on which water does not act; and a piece of resin remains unchanged in water, but disappears when placed in alcohol. Those bodies which thus unite are said to have an affinity for each other, as the alcohol and resin, or the alcohol and water, which also combine. Some have a stronger mutual affinity than others, and seem to prefer combining together, rather than with other substances. Thus, if water be added to the solution of resin in alcohol, the two liquids combine, and the resin falls down in a solid state. Most liquids will only combine with a certain quantity of a solid body, as water, which only dissolves so much salt or sugar, the remainder falling to the bottom. The liquid is then said to be saturated. Heat generally increases the power of solution; thus, water at the usual temperature dissolves about thirty-five parts in a hundred by weight of common salt, and at the boiling point about five parts more. Water and other liquids also dissolve or absorb various gases or aerial bodies. Thus, water will absorb rather more than its own bulk of that fixed air, or carbonic acid, which is seen escaping from beer or soda water when poured into a glass. Other gases are also absorbed by water, some in a greater, others in a less proportion. In the solution of solids cold is generally produced,—in the absorption of gases heat more often results.

Chemical attraction, in its highest form, is seen where simple

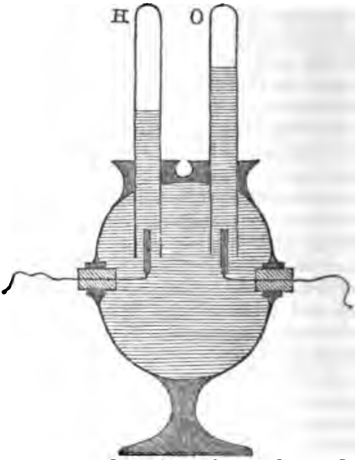
elements unite to form compound bodies, and often acts even in opposition to cohesion, though generally modified by it. In such combinations the substances unite only in *definite proportions*, that is, the amount of the one bears a fixed and certain relation to that of the other; or where more than one compound can be formed by two substances, the quantities of these in the second compound are simple multiples of those in the first. Thus, mercury unites in two proportions with oxygen; in one case 200 parts of mercury with eight of oxygen forming a black tasteless powder; in the other, the same amount of the metal unites with sixteen parts of the gas, and forms a red shining mass with a sharp metallic taste, which is soluble in water. This example shows also that in combination the properties of the bodies are much changed, the bright silvery white metal, united with an invisible air, being turned in one case into a black, in the other into a red powder, with properties as different in each case as the colours. Such combinations in their formation are almost always accompanied with a change of temperature, and in some cases both light and heat are given out in great abundance. It also often happens that this union will not take place when the substances are mixed at the usual temperature, but requires the influence of heat. Thus copper filings and sulphur, though mechanically mixed, exert no action on each other till they are warmed so that the sulphur is melted, when it combines with the copper, which becomes red-hot and forms a black brittle substance. In this, sixteen parts of sulphur unite with sixty-four of copper; but another combination of thirty-two parts sulphur with sixty-four of copper is more common in nature, forming the ore whence most of this metal is procured, though it cannot be produced artificially. These examples will illustrate this most important chemical law.

All bodies have not an equal tendency to combine together, but some are more ready to unite than others. Hence, if three substances be mixed, two of them will often combine, whilst the third remains separate. Where again a compound formed of two substances is mixed with a third, which has a stronger affinity or attraction for one of them than they have for each other, the first compound is in many cases dissolved, and a new one formed in its stead. Thus, the barilla of commerce, consisting of carbonic acid and soda, if put in sulphuric acid is dissolved, and the carbonic acid escapes like bubbles of air, named effervescing, and a compound of the soda with the sulphuric acid is formed. But if hot lime is boiled in a solution of this barilla in water, it is again decomposed, and the carbonic acid, uniting with the lime, forms carbonate of lime, or

common chalk, whilst the soda is left alone. This preference of one body for another with which to enter into composition, is named elective affinity. In this manner numerous substances may be decomposed and reduced to their simple elements.

Decomposition is also effected by voltaic electricity, which, when passing through a compound body, has a tendency to cause one part of its components to collect at one pole and another at the opposite one. Thus, water consists of two gases, hydrogen and oxygen, and when a current of electricity passes through it, is resolved into these. This is done in the manner shown in Fig. 71, where two platinum wires are introduced into a vessel of water, and being connected with a galvanic pile, the gases which form over them are collected in the inverted jars H and O. That in H, over the negative wire, is found to be hydrogen, and to be twice the volume of that in O over the positive pole, which is found to be oxygen. When these two gases are mixed in this proportion in a close vessel, and burnt by an electric spark passed through them, they again combine and form water.

Fig. 71.

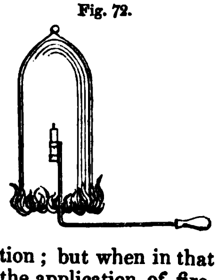


By decomposing in this manner the various compound bodies observed on the earth, they have been found to consist of a small number of elementary substances which cannot be further reduced. The ancients spoke of four elements; but they had no knowledge of the composition of bodies in the present sense of the term, and their elements are in reality the four classes into which substances may even yet be divided—earths or solids; water or fluids; air or the gaseous bodies; and fire, representing the imponderable substances or agents of heat, light, and electricity. In the modern sense of the term, fifty-four substances are known, which, having never been decomposed, are regarded as simple elements. Four of these, Oxygen, Hydrogen, Nitrogen, and Chlorine, are gaseous in the ordinary conditions of atmospheric temperature and pressure. Oxygen, the first of these, is without any colour,

taste, or smell, and continues gaseous under all known circumstances. It was discovered by Priestley in 1774, and is named from two Greek words signifying to produce acids, which were then believed to owe their peculiar characters to this body. It is one of the most widely distributed substances in nature, composing one-fifth part of the atmosphere in volume, and eight-ninths of the waters of the globe in weight. Oxygen enters also into the composition of nearly all the solid bodies composing the earth, forming probably one-half of the substances seen on its surface. It is also of very great importance in most natural processes, as the respiration of animals, which cannot exist without it, the growth of plants, and combustion, which is in general a mere union of this substance with some other, especially carbon. This gas combines with almost every substance in nature in one way or another. Its most remarkable property is the great facility and splendour with which bodies when ignited burn in it. Phosphorus placed in a jar of oxygen exhibits so brilliant and intense a light as to be scarcely tolerable to the eye; and a piece of iron also, previously rendered red-hot, burns in it very readily. Some of its compounds will be noticed subsequently.

Hydrogen, also found in the gaseous state, is named from its property of forming water with oxygen, and is usually obtained by decomposing that fluid. This is accomplished by mixing sulphuric acid, diluted in water, with filings of iron or zinc, when the oxygen combines with the metal, and the hydrogen escapes as a gas. It is without colour or taste, but has a disagreeable smell. Hydrogen when breathed destroys animals, and will not support combustion, but is readily inflammable when oxygen is present. This is shown by the following experiment (Fig. 72). Bring a lighted taper to the mouth of a jar full of this gas, it will take fire and burn round the opening where it mixes with the oxygen of the atmosphere, but the taper is extinguished when immersed in the hydrogen. It is the lightest known substance, weighing only a fourteenth of an equal bulk of air, one-11,798th of water, and one-247,758th of platinum, the heaviest known body, which is thus nearly a quarter of a million times its weight. It, however, mixes readily with oxygen in any proportion; but when in that of two to one, the mixture explodes on the application of fire, and water, as formerly stated, is the result. This is a curious example of the changes which combination effects on the pro-

Fig. 72.



perties of elementary substances. Two light impalpable gases are thus formed into a liquid, which, at a certain temperature, becomes solid. The common properties of water are too well known to be repeated here; though it is deserving of remark that much of its utility arises from its want of any sensible quality, its being colourless, tasteless, and inodorous. Water congeals at 32° of Fahrenheit, and boils at 212°, when it changes into vapour or steam, which is 1696 times its former bulk. When freezing it also expands, attaining its greatest density at seven degrees above the freezing-point, and increasing by about an eighth part on being changed into ice. This property of water is of much importance in many natural processes, and is the reason why liquids in freezing burst the bottles or pipes in which they are contained. As oxygen is sixteen times the weight of hydrogen, water contains eight grains of the former to one of the latter.

The third gaseous element is Nitrogen, so named from its composing nitre; also often called azote, a word from the Greek signifying to destroy life. It neither affects the sight, taste, nor smell, and has no remarkable properties. It forms four-fifths of the atmosphere; but its chief use seems to be to dilute the oxygen, as without it life, combustion, and other natural processes, would go on with destructive rapidity. It is not inflammable, and does not combine directly with oxygen; yet indirectly, it forms five distinct compounds. One of these is the nitrous oxide, or intoxicating gas, consisting of one atom of each of the two gases. When breathed it produces a state of excitement resembling intoxication, which continues, however, only for a minute or two. In nitric acid, nitrogen combines with the largest proportion of oxygen, or each of its atoms with five of the oxygen, and forms a liquid which dissolves all the common metals except gold and platinum. It is named an acid from its taste, and is one of a class of bodies mostly having a sour taste, turning vegetable blue colours red, and combining readily with alkalies, earths, and metallic oxides. Their general properties, however, are not easily defined. With hydrogen, nitrogen forms a compound named ammonia, one of an opposite class of substances named alkalies. These are soluble in water, have a sharp bitter taste, are caustic, or corrode animal and vegetable matter, and turn vegetable blues to green, and yellows to brown. They combine readily with the former class of substances, or acids; and in certain proportions the two neutralize each other, when their peculiar properties are destroyed. The mixture no longer affects vegetable colours, is neither acid, corrosive, nor caustic, but has a bitter saline taste, and forms one of a new class of substances named salts. Ammonia exists as a

gas, absorbed in a large proportion by water, which can take up 670 times its volume, and thus acquires a peculiar taste and smell, and becomes lighter than formerly. Common nitre, so much used in the preparation of gunpowder, is a compound of nitric acid and potassa.

Chlorine, named on account of its colour, from the Greek word signifying green, is the last of the gaseous elements. It has an astringent taste, a suffocating smell, and when breathed, its action on the lungs is extremely painful and injurious. A taper burns readily in it with much smoke, phosphorus ignites of itself, and thin plates of tin, copper, or zinc also consume when immersed in this gas. It destroys vegetable colours when moisture is present, and hence is used in bleaching; it also removes offensive animal and vegetable effluvia, with their infectious properties, and is consequently employed in fumigation. Chlorine combines with hydrogen, and forms a gas named the hydrochloric acid, of which water can absorb about 480 times its volume, the solution forming the well-known muriatic acid or spirit of salt.

There are eight other non-metallic elements, of which five, Bromine, Iodine, Sulphur, Phosphorus, and Selenium, are volatile, or rise in vapour with a moderate degree of heat; two, Carbon and Boron, are not volatile; and one, Fluorine, is only known in its compounds, having never been shown separately. These are all solid in the natural state, except Bromine, which is fluid. The most important of these are Sulphur, Phosphorus, and Carbon. The first, well known as a brittle yellow solid, is found native near volcanoes, from which it seems to be sublimed or raised in a state of vapour, which condenses when cold, and is also artificially prepared by a similar process from some of its compounds, especially the sulphuret of iron. It melts easily, is volatilized at a low heat, and takes fire with much facility; in the latter case forming, with an equal amount of oxygen, the sulphurous acid gas, well known from its pungent suffocating smell. This is rapidly absorbed in water, and is used for whitening some substances, as silk and straw. With a half more oxygen, the sulphuric acid or oil of vitriol is formed—a heavy colourless oily fluid, intensely sour. This is the strongest of the acids, and shows the most powerful affinity for the alkalies and many of the earths. It dissolves iron, zinc, copper, and silver, and is used in many manufactures. Green vitriol is a compound of it with oxide of iron. With hydrogen, sulphur forms sulphuretted hydrogen gas, well known for its offensive fetid odour, and as contained in many mineral waters.

Phosphorus, as usually obtained, is soft and of a flesh-red colour, but may be procured colourless and transparent. It is very inflammable, and must be kept in close bottles under water.

In the atmosphere it emits a light smoke with a peculiar smell, and readily takes fire when rubbed against any hard substance, as exemplified by the common phosphorus matches. Phosphorus is procured from bones, into which it enters in combination with lime.

The next non-metallic element, Carbon, is more important, and forms more remarkable compounds. That from charred wood is black, inodorous, tasteless, very porous, and readily absorbs or condenses various gases. Carbon is insoluble in water, cannot be melted or vaporized by heat, is not affected by any acid except the nitric, and is little altered by exposure to air or damp. It burns readily in the atmosphere, and with much brilliancy in oxygen gas. Coal consists principally of carbon, and in coke it is still more pure, though mixed with earthy matters. The diamond seems almost pure carbon, aggregated in a particular way. Ivory-black and lamp-black are also forms of this substance; and the black-lead used for pencils consists almost entirely of it, with a little iron, but no lead. When burned, carbon combines with oxygen, and forms carbonic acid, a colourless inodorous gas, heavier by one-half than common air. This is the choke damp of mines, where it speedily destroys life or combustion, and also the fixed air found in fermented liquors and in soda-water. When compressed by a weight equal to thirty-six atmospheres, it is condensed into a liquid. Combined with lime, it forms chalk, marble, and other limestones, and also shells and corals. Carbonic acid gas is produced during combustion and respiration, and is decomposed by vegetables, a small proportion of it being always mixed with the atmosphere. With hydrogen, carbon forms three compounds. One is light carburetted hydrogen, a very inflammable gas, exploding readily when mixed with oxygen or common air. This is the fire-damp of the coal mines, to which so many accidents are owing. The olefiant gas, or carburetted hydrogen, is the basis of common coal gas, and contains twice the carbon of the former. Naphtha, a light yellow volatile liquid, is a third compound of carbon and hydrogen, and is used for dissolving caoutchouc, which can thus be moulded into various forms.

The metallic elements embrace not only those metals which we usually designate by this name, but some other similar substances which in nature are only found in a compound state. When combined with oxygen, some of these are named earths, whilst others form alkalies. Of the latter there are three, Potassium, Sodium, and Lithium, the last rare and unimportant. Potassium is soft, malleable, and white like silver. It has a strong affinity for oxygen, and in the air quickly combines with

it, and forms a white powder named potassa. When thrown on water, the metal decomposes this fluid, burns with a reddish flame, and continues moving rapidly about on the surface till it is all consumed. The result of this action is again potassa, or caustic potash. That of commerce is usually impure, and contains water. Pearl-ash, as it is termed, is a carbonate of potash, and is usually formed from the ashes of wood and vegetable matter. The metal is formed by decomposing the potash, and is never found in nature. Sodium is formed in the same way from soda, but with more difficulty. It resembles the former in most points, attracting oxygen from the air and water, but with less violence of action. The result is soda; but the carbonate of this, prepared from sea-weeds, and also found native, is better known. Sodium burns in chlorine, and forms chloride of sodium, or common salt. This is procured from evaporating sea-water, or from springs and beds of rock-salt found in many countries, and has now become a necessary ingredient in human food, besides being extensively employed in the arts.

Of the earths, some have much resemblance to the alkalies, and like them consist of a metallic basis combined with oxygen. These are, Calcium, Barium, Strontium, and Magnesium, forming the earths lime, baryta, strontia, and magnesia, the first and last being most important. Lime is procured by expelling the carbonic acid from common limestone by heat, when it forms caustic lime, which readily absorbs a certain amount of water. The properties of this body and its various uses are well known. With sulphuric acid it forms alabaster and gypsum, which when burnt falls into a fine white powder named plaster of Paris. This readily absorbs water, and forms a paste which soon sets into a firm mass, and on this account is much employed in taking casts. Combined with chlorine, it forms chloride of lime or bleaching-powder, being much used for this purpose. The properties of magnesia are not greatly different from those of lime, with which it is often found united in nature.

Silicium, Aluminium, Thorium, Glucinium, Zirconium, and Ittrium, combined with oxygen, form other earths, of which the most abundant are silica and alumina. Silica is one of the most common substances known, quartz, flint, and sandstone consisting almost entirely of it. When pure it is white, hard, insoluble, and only fusible at a high temperature. It forms some of the precious stones; and glass is principally composed of it, with potassa or soda. Its base has not been obtained alone in much abundance, and its nature is not well ascertained. Many chemists regard it as of a metallic nature, whilst others consider it as more closely allied to the non-metallic elements, and name it Silicon. In composition with other substances,

also, silica seems to unite with these in the manner of an acid. Alumina is that earth which gives to clay its soft, plastic, and adhesive character. It is a very common ingredient of rocks, and forms some precious stones, as the sapphire, turquoise, and ruby. Porcelain, earthenware, tobacco-pipes, and bricks, consist of it in more or less purity.

Of the Metals commonly so called, Iron is one of the most important. It is extracted from various ores, principally compounds of it with oxygen or carbonic acid, which are found in vast abundance in various countries. These are melted in furnaces and cast into different forms, producing cast-iron, which, besides several impurities, contains a proportion of carbon. When this is removed by heat, and the metal rolled and hammered, it becomes wrought or malleable iron, which is tougher, stronger, and less fusible than the former. Steel is a compound of pure iron and carbon, formed by exposing iron bars mixed with charcoal to a high temperature and then hammering them. It is much harder, more elastic, and takes a finer edge and higher polish than common iron. There are two compounds of this metal with oxygen, of which the peroxide, forming *iron* rust, is the best known. With the acid from gall-nuts it forms the colouring matter of writing ink, and Prussian blue is a compound of it with ferrocyanic acid.

Zinc is another metal now much used for economic purposes, as it does not readily rust through exposure to air or moisture. It is of a blueish white colour, fine metallic lustre, and malleable at a temperature a little above that of boiling water. Tin is also a white, brilliant metal, not easily affected by exposure to the atmosphere, and hence for some purposes iron is covered with a thin coating of it to prevent rust. Sheet tin is thus formed of thin plates of iron coated with the other metal. Alloyed or mixed with copper it forms bronze, bell-metal, and when in the proportion of about a third, the fine white metal used for the specula of reflecting telescopes. Lead is of a duller colour, is much softer, and has less tenacity than tin. When exposed to the air it becomes covered with a thin film of carbonate of lead. At a high temperature it combines with oxygen and forms litharge, of a yellowish colour; or, with more oxygen, red lead, used as a pigment. White lead is a carbonate, and sugar of lead an acetate or combination with vinegar, of the oxide of lead. The latter is very soluble, and has a sweetish taste, but is poisonous, its effects however being counteracted by the sulphate of soda or magnesia. Copper is known by its red colour. It is a malleable ductile metal, and forms strong tenacious wires. On exposure to the air the surface is oxidated, and a carbonate of a green colour, is formed. The sulphate is known as blue

vitriol, the carbonate as blue verditer, and the acetate as verdigris, all of which are poisonous. Brass is one of its compounds with zinc, and possesses properties which render it preferable for many purposes to the simple metal—being harder, more durable, and less affected by exposure to the atmosphere.

Mercury is the only metal fluid at ordinary temperatures. It becomes solid at 39° below zero of Fahrenheit, when it is malleable and so soft that it may be cut with a knife. It is found pure or native, but is mostly prepared from the sulphuret or cinnabar, which also forms a fine red pigment named vermilion. With chlorine it produces a white powder, the well known and useful medicine named calomel. Silver, one of the earliest known metals, is much valued for its beautiful white colour and great lustre. It is very malleable, and so ductile as to be drawn into threads finer than a human hair. Silver is much used for ornamental articles and for money, when it is usually alloyed with a thirteenth part of copper to render it harder. It is found in mines either pure or combined with metals and other substances, especially sulphur. Gold is much esteemed for its rich yellow colour, its fine lustre, and unalterability, which fit it especially for ornaments. It is the most malleable and ductile of the metals, and can be beaten into plates or leaves of which 28,000 are only an inch thick. Oxygen, even with intense heat, does not affect it, and it only dissolves in a mixture of muriatic and nitric acids, named aqua regia. Mercury dissolves it with great facility, and forms an amalgam much used for gilding metals. Gold coin is also alloyed with copper to render it harder and more durable. Platinum, only found in the metallic state, is the heaviest of all metals. Its colour is white, resembling iron, like which it may also be welded together at a white heat, but it is very infusible, and like gold only acted on by the aqua regia. Platinum is principally found in Russia, where it is used for coins, and has a value nearly equal to that of gold. It is also much employed for chemical apparatus, for which it is well adapted by its capacity of resisting heat and acids. The other metals, whose properties are less remarkable, and which are applied to fewer purposes than those now described, are Manganese, Cadmium, Cobalt, Nickel, Arsenic (the well known and very active poison being a combination of this last with oxygen), Chromium, Vanadium, Molybdenum, Tungsten, Columbium, Antimony, Uranium, Cerium, Bismuth, Titanium, Tellurium, Palladium, Rhodium, Oxmium, and Iridium.

These elementary substances in their varius combinations form all those innumerable bodies composing the animal, vegetable, and mineral kingdoms. In the last, all the elements are

found, simple minerals containing sometimes one, sometimes more of them in definite proportions. That branch of chemistry which teaches the nature of the metallic ores, and the manner of reducing them so as to procure the metal they contain, is named Metallurgy, and is a subject of great practical importance. Several of the elements have not been found in organic bodies, which seem to consist essentially of a very few of them. Thus animal bodies are composed principally of oxygen, hydrogen, carbon, and nitrogen, or those elements found in water and the atmosphere. With these, phosphorus and calcium or lime occur in considerable abundance, forming the earthy matter of the bones. Less abundant are sulphur, iron, manganese, silicium, iodine, and chlorine. The ultimate elements of plants are essentially oxygen, hydrogen, and carbon. . Nitrogen is also common in some classes, though less so than in animal bodies. Silica, lime, and magnesia, the alkalies potassa and soda, sulphur, phosphorus, and several of the metals, are also found in particular plants. In organic bodies these elements combine together in definite proportions, forming what are named proximate principles. These, either singly or again combined, form the various elementary tissues of animal and vegetable bodies, and also impart to them their peculiar properties. Many of the functions of plants and animals arise in chemical changes in the organs or the substances contained in them, modified, however, in a manner unknown to us by the principle of life. Hence arises the great importance of a knowledge of the facts and principles of chemistry to the successful study of the natural sciences.

END OF PART I.

INTRODUCTORY BOOK OF THE SCIENCES.

PART II.

Natural Sciences.

Section I.—MINERALOGY.

Natural History, taken in its most general acceptation, should comprise the whole laws and phenomena of nature, and would thus encroach on those sciences treated of in the former part of this work. It is now, however, generally used in a more limited sense, and restricted to the consideration of objects actually existing and made known to us by direct observation. It endeavours to distinguish these from each other by permanent characters, to classify them according to their true connexions, and to point out their peculiar properties and uses, especially with reference to the wants of mankind. The first great division of its objects is into organic and inorganic; the former comprising those bodies which possess a structure varying in different parts, which form distinct organs, designed for particular purposes or functions; the other, those which have no such distinction of parts or functions, but a structure and composition uniform throughout. The former also possess life in a greater or less degree, and consequently grow, exist for a definite period, and die or decay; whereas the latter are inanimate, properly neither grow nor decay, have no fixed duration, and no individuality of being. Thus, a tree has roots, branches, leaves, and flowers, an animal head, trunk, and limbs, each distinct and growing by an internal increase; whereas a stone, as a piece of chalk or flint, is uniform in every part, or exhibits mere accidental differences.

The whole of inorganic nature is comprehended under the science of Mineralogy, taken in its widest sense. Even the earth itself, and its three great divisions of land, water, and atmosphere, form objects included in the mineral kingdom. Part of this is, however, now considered under the science of Geology, which treats of rocks, their mode of origin and relations; whilst another part, regarding the form of the earth's surface and the distribution of its various parts, is the object of

Physical Geography. Mineralogy is now confined to a description of those inorganic bodies which are of uniform composition and possessed of a regular structure. Most minerals assume certain determinate angular forms, bounded by plane or straight lines, named crystals. These are seen in most cases where a mineral is formed from its solution in water, and also when melted sulphur and some metals are allowed to cool slowly. Each mineral species has a particular form which it assumes; as carbonate of lime that of a rhomb, fluor-spar of a cube, and common quartz of a six-sided pyramid. In nature these crystals have very various and complicated shapes, but all these may be shown to arise from combinations of a few simple primary forms.

Of simple minerals, distinguished from each other by colour, form, hardness, weight, and other qualities, about four hundred species are known; but many of these are rare, and chiefly valued as curiosities. Numerous classifications of minerals have been proposed, but as none of these is in very general use, it is needless to enter into details. The metals form a large and important class of minerals, already described; and their ores, with the places where they occur, will be afterwards noticed. The earthy minerals consist principally of the earths, and have little or no taste or smell. A few of them compose almost the whole rocks forming the crust of the earth. One of the most abundant is quartz, which in general is almost pure silica, slightly coloured by iron. Common quartz is white, gray, or reddish in colour, and more or less transparent. This mineral is found in rocks of all ages, and is even deposited from springs at the present day. The sandstone of which Edinburgh is principally built consists almost entirely of quartz. Another common mineral is felspar, of a white or red colour, but less hard than the former. It consists of silica, combined with alumina and potash, and is found abundantly in igneous and other rocks. Mica, well known from its transparency and bright silvery colour, and the facility with which it divides into thin elastic plates, is also common, especially in the older formations. Hornblende and augite, sometimes thought to be varieties of one mineral, are also abundant, and have a dark green almost black colour. These minerals now mentioned compose the great mass of the rocks found on the earth, but a few others may be noticed. Lime occurs in various forms, especially the carbonate, which is often pure and crystalline like quartz, but soft and effervescing with acids. Less pure varieties form the limestone and marble rocks, in some varieties of which it is combined with magnesia. The sulphate of lime or gypsum is used for many purposes. Iron is also

very abundant, but generally as an oxide entering into the composition of other minerals.

The gems or precious stones, valued for their colour, transparency, lustre, hardness, and susceptibility of polish, are an interesting class of minerals. The diamond, the most esteemed of the whole, consists of pure carbon, having almost the same chemical composition with some varieties of coal. One of the largest, brought from the East Indies, belongs to the Emperor of Russia, and is rather less than an inch high, and about an inch and a quarter in diameter. The Pitt diamond, belonging to the French king, is smaller, and is valued at £300,000. The greater number come from Hindostan or Brazil, but a few small ones have been found in the Ural Mountains. The corundum, ruby, and sapphire, are nearly pure crystallized alumina, which in its common forms composes most of our earths and clays. The sapphire has different names according to its colour, which is white, blue, purple, yellow, or green. The ruby is blood or rose red, and the corundum, of which common emery seems merely a variety, usually gray or greenish coloured. Silica furnishes many ornamental stones, as the pure colourless rock-crystal, the brown Cairngorm, the violet-blue amethyst, the gray, green, or blue chalcedony; the variously-striped and coloured onyxes, agates, and jaspers; the dark-green heliotrope, named bloodstone from its red spots; and the milky white opal, distinguished by its beautiful play of colours. Other gems are a combination of these two substances, as the green emeralds of Peru and Brazil, the euclase, the garnet, and the beautiful blue lapis lazuli, from which ultramarine is prepared, the colouring matter being probably iron.

The combustible minerals are also very valuable. In this class might be reckoned the diamond, and amber, supposed to be the gum of some extinct tree. Sulphur is also combustible; but it is only the varieties of coal which are used for fuel. Saline minerals or native salts also occur, the most common being rock-salt or chloride of sodium, nitre or saltpetre, sal-ammoniac, borax, alum or sulphate of alumina, and natron or carbonate of soda. These few minerals mentioned will show the importance of this science, and the many valuable substances which it furnishes for the use of man.

SECTION II.—GEOLOGY.

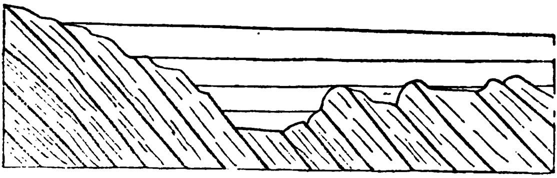
THIS science, in its most limited signification, is applied to the description of the rock-masses composing the earth, the mode of their formation, and the manner in which they are arranged, or their relations to each other. Rocks are distinguished by various characters, derived from their composition, structure, and external forms. In regard to the first, some are simple, consisting only of one mineral, as limestone or quartz rock; whilst others are compound, consisting of two or more, as granite of quartz, felspar, and mica. In structure some are granular or crystalline, that is, composed of parts with distinct angular forms; others fragmentary, of materials broken, and partly at least worn and rounded, like the pebbles found in the bed of a river or on the seashore. In respect to external form much difference also occurs, some being disposed in irregular masses, whilst others are divided into beds or strata. The latter distinction forms the basis of the first great division of rocks into stratified and unstratified; the former supposed to have been produced by the action of water, the latter by that of fire. The stratified rocks occur in a regular order in the earth, which, except that some of them are at times wanting, is the same every where: the unstratified have forced their way among these at various times, and in no certain order.

Strata are supposed to have been formed from matter carried down by rivers into the sea or lakes, and there deposited in beds, which have been consolidated in various ways. This is confirmed not only by the character of the materials composing them, but by the remains of fresh and salt water animals found in them, and by many other marks of an aqueous origin. They are considered to have been originally horizontal or level, but now, however, are found raised up and sloping with various declivities, as in Fig. 73. Sometimes they follow each other

Fig. 73.

regularly like the leaves of a book; at others, one class rests on the end of another, Fig. 74, when they are said to be uncon-

Fig. 74.



formable. When many strata found in connexion agree in several characters, and appear to have been formed during one period in which the condition of the earth's surface underwent little change, they are said to belong to one formation. In this way the almost innumerable beds are divided into a few large groups, with similar characters, which are more easily remembered and described than if each stratum were taken separately. In distinguishing these, the mineral character and appearance of the rock is not to be alone attended to, since these often change from place to place. The cause of this is obvious, the coarser and heavier substances brought down by the rivers being deposited near their mouths, whilst the finer were carried farther out to sea. Various remains of plants and animals are found in the rocks, and these, being generally different in each formation, serve to distinguish one from another even in distant lands. These fossil remains, or petrifactions as they are called when changed into stone, in the older rocks are all different from any animals or plants now existing on the earth; in the newer formations, the generality become more like those presently known, and some are not to be distinguished. Many petrifactions found in the rocks of this country seem to have been natives of warm and tropical lands, the animals being larger and the plants apparently more luxuriant than those of the north of modern Europe. Hence it has been supposed that the climate of this part of the earth was then warmer than at present, and, as the same fossils are found in the rocks of far distant lands, that a greater uniformity of temperature prevailed over the globe. As might be expected from the strata having been generally formed in the ocean, these fossils consist principally of the remains of animals which have inhabited the salt water, especially mollusca, whose hard calcareous shells are well fitted for preservation. Amongst the plants, also, the most abundant are those which are least liable to decomposition in water.

These remains of organized beings thus form a kind of history

of the globe in past times, enabling us to know something of its former condition, and the changes it has undergone. Each bed is like a leaf from an old chronicle, telling what was the state of the earth at the time it was formed. But only a few of these leaves have been preserved in one place; and though the defects may be partly supplied by those found in other situations, yet it is probable some have altogether perished, and a complete series is nowhere to be obtained. We therefore only know fragments of the past history of the earth, though new discoveries are always making this more complete. The various strata are usually arranged according to age, those found deepest in any place being considered as the oldest, having necessarily been formed before those which rest upon them, as in Fig. 74, where the shaded beds must evidently have existed and been raised up before the unshaded beds were deposited above them. In the classification of Werner, the celebrated German geologist, which, with a few modifications, is most generally adopted, there are five classes, each containing several formations. These classes are:—

I. Primary or crystalline strata, named also metamorphic, as being changed from their original character.

II. Transition rocks, the oldest unaltered strata, with few fossils, and these principally in the upper beds.

III. Secondary rocks; strata very generally distributed over wide areas, and with many fossils.

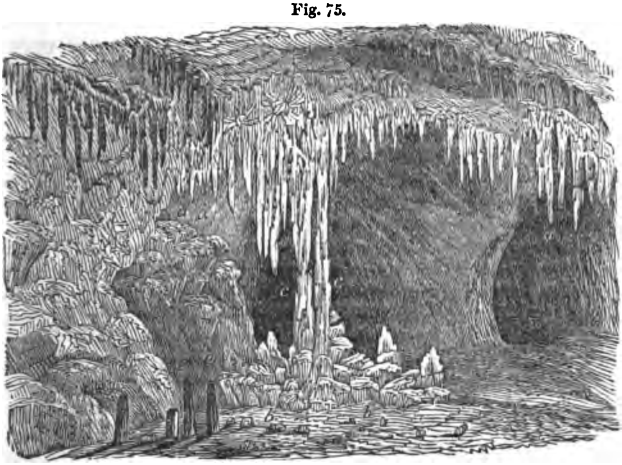
IV. Tertiary rocks, found only in more limited spaces to which they seem peculiar. They contain fossils, of which numbers are found existing at present.

V. Alluvial formations, forming by causes now acting, and containing remains only of plants and animals still living.

In describing these we shall begin with the second class, or Transition Rocks. In England these have been divided into two formations:—The Cambrian, consisting of soft dark-coloured slates with no fossils, and of other slates and limestones with a few fossils; and the Silurian, also of slate, limestone, and graywacke, with more numerous remains, especially shells and corals in the limestone beds. In Scotland this class of rocks is mostly slate, graywacke composed of angular fragments of other rocks and minerals, and a few beds of limestone, with almost no fossils. It contains many mines, as of lead, at the Leadhills in Scotland; of tin and copper, in Cornwall; of iron, silver, and other metals, in the Hartz in Germany. In one of the mines here, a piece of silver ore was found weighing a hundred pounds, and valued at £240. The black-lead mines of Borrowdale, producing the purest kinds of this mineral in the world, are in these rocks; and in Spain quicksilver is also found in them.

The Secondary Rocks are more numerous, and show greater varieties, especially of organic remains, which now become far more abundant. The principal formations are the following:—(1.) The Old Red Sandstone, consisting, as its name implies, of coarse or fine sandstones, that is, rocks composed of grains of quartz or sand adhering to each other, and generally of a dark red colour. Where these rocks consist of larger rounded fragments, it is named a conglomerate, and such coarse varieties are found among most sandstone deposits. It contains several fossils, of which the most remarkable are fishes of peculiar shapes and forms. (2.) The Mountain Limestone, composed principally of a dark black variety of this rock, with many fossils, as shells and corals, especially those named encrinites. At Burdiehouse, near Edinburgh, many curious fishes were found in it. In the north of England it contains mines of lead, and in Derbyshire also other metals, and the beautiful blue fluor-spar. It also contains many caves, as Peak's Hole in that county, nearly half a mile long, and in some places 120 feet high; and in other countries still more remarkable ones occur. The water oozing through these rocks dissolves (Fig. 75) part of the lime, which is again deposited in the air, forming stalactites, *a*, *a*, when suspended from the roof; or stalagmite, *b*, *b*, on

Fig. 75.



the floor; these sometimes uniting into pillars, *c*, *c*. In some of these caves, the bones of extinct animals have been found buried in mud, or incrusted with this new formation of lime.

(3.) The Coal Formation, consisting principally of a white quartzy sandstone, of slate-clay, often containing bitumen, and of coal. These rocks are generally in regular even strata, filling valleys between mountains of the former rocks. In Europe they are often below the level of the sea, and seldom rise high above it, but in Peru are found at ten thousand feet of elevation. Britain and the United States of North America contain this valuable mineral in most abundance. Fossils, especially plants, are very common in this formation, particularly in the sandstones and shales. Some resemble gigantic ferns and reeds, others palms like those of the torrid zone, and others coniferæ like our pines. These trees are often of large size and nearly erect; others are inclined, compressed by the weight above, and their roots and branches broken. Fresh-water shells are also not uncommon, and some beds consist almost entirely of them. Coal is composed chiefly of carbon, with hydrogen, oxygen, and nitrogen in various proportions, the different varieties depending on the amount of the latter elements. The anthracite coal is nearly pure carbon, and burns without flame, whence it is named in some districts blind-coal. This mineral is now believed to be of vegetable origin, formed from the forests and luxuriant vegetation of former periods. Its present character has been produced by long submersion in water, and the great compression it has experienced. Coal is seldom found on the surface of the earth, and the mines or pits are often of great depth, many of those both in Scotland and England reaching far below the level of the ocean. It is curious that very extensive beds of iron ore are found along with this mineral, which is so necessary to render it available for the wants of man. Most of the British iron is indeed procured from this formation, on which it may be affirmed that much of the prosperity and character of the nation depends.

(4.) The New Red Sandstone, and (5.) the Magnesian Limestone, have few peculiarities except those expressed in their names. In Germany the latter contains beds of copper ore, wrought in many places. (6.) The Variegated Sandstone is named from the colour of its beds, usually striped and spotted with red and white. In it beds of gypsum and of rock-salt frequently occur. The latter is usually in huge granular masses of a white or gray colour, and though soft, has yet to be broken up by gunpowder. In Cheshire the beds are from four to 130 feet thick. Numerous salt-springs also occur in this formation, from which the salt is extracted by evaporation. That forming the rocks is seldom so pure that it can be used, and must be dissolved in water and crystallized anew. (7.) The Lias Formation, consisting principally of a blueish gray clayey lime-

stone, with shales and marls, contains many curious fossils. Plants are so abundant as in some parts to form beds of lignite or wood coal, but far less valuable than that formerly noticed. Numerous remains of saurian animals, so named from their resemblance to lizards, also occur. One of these, the Ichthyosaurus, or fish-lizard, had a large head, with numerous teeth resembling those of the crocodile; the eyes were very large, the neck short, and the body, with many ribs and four short feet or paddles, ended in a long tapering tail. It had thus the head of a lizard, the teeth of a crocodile, the backbone of a fish, and the fins of a whale. The general outline has resembled that of the porpoise, and like this animal it appears to have lived in the waters, subsisting on fish and small animals even of its own kind. The Plesiosaurus resembled the former in many points, but had a smaller head and a long serpent-like neck. These creatures are supposed to have lived in the shallow waters of calm bays, lurking for their prey among the reeds, or seeking it, like our present swans, at the bottom. Some of them are believed to have been twenty-seven feet or more in length. The Megalosaurus, forty feet long, has been a still larger species. The Pterodactylus was a winged reptile of very curious structure. In its head and long neck it resembled a bird, its wings were those of the bat, and its body and tail similar to those of modern mammalia. Their bills or jaws were armed with teeth, and they seem to have lived on insects, seeking them, it is probable, both on the land and water. Such are a few of the strange creatures that inhabited the earth at that early period.

The next group of rocks is the Oolite, the egg or roe-stone, so named from its consisting of numerous small round concretions like the roe of a fish. It forms two divisions, the Lower Oolite (8.), and the Upper (9.) The former consists in England of various beds of limestone, of the characteristic structure, with others of marl, sandstone, and compact limestone, known by various local names. The upper, in like manner, consists of blue marls; and limestones, compact, clayey, or sandy, and of a blue, gray, or yellow colour, also distinguished by particular names. One of them, the Oxford clay, contains many fossils, by which it is easily known even at great distances. The lithographic slate, first found near Solenhofen, in the Jura, is a yellow or smoke-gray limestone of this formation, and is also remarkable for its numerous fossils, among which are dragonflies and other insects. On the coast of Dorsetshire, the remains of a forest, the roots of the trees still standing upright and fixed in the soil, have been found in the oolite. In the Weald clays, a small local formation above this, is found the Iguanodon, apparently the most gigantic reptile of the ancient world. The

bones of its thigh have surpassed those of the largest elephant, and Dr Mantell estimates the animal at seventy feet long. Above this is the Greensand (10.), named from a quartzy sandstone mixed with particles of green earth. The Chalk Formation (11.) is named from the well-known soft earthy limestone so called. In this are found numerous concretions, or irregular rounded masses of flint. These are generally in horizontal layers, sometimes united, at others separated. It is usually of a brown colour, striped or spotted with white, and is much used for gun-flints and in the manufacture of glass and porcelain. The chalk is now known to consist almost entirely of the calcareous shells of minute microscopic animals, and the flint of others of a siliceous character. The salt-mountain of Cardona in Spain, 300 feet high, composed of pure transparent white salt, mixed with red or brown, and which has been quarried more than seven hundred years, is in this formation. The salt-mines of Wieliczka, at the foot of the Carpathian Mountains, are also in this rock. They are 1100 feet deep, and produce one and a half million hundredweights of salt every year. The chalk is considered the last or uppermost of the secondary rocks.

The Tertiary Formations are in general less extensive than those we have now been considering. They seem to have been formed in small basins at the mouths of rivers, where the fresh and salt water alternately prevailed. Though none of the deposits can be traced in distant localities, and consequently no general classification be formed, yet rocks belonging to this class have been met with in almost every quarter of the globe. Mr Lyell proposes to divide these strata according to the number of recent fossils they contain, these always becoming more abundant as we come nearer to modern times. He names the oldest Eocene, a name signifying the dawn of the recent species, with only from three to five per cent. of shells now found in the ocean. The next class is the Meiocene, with more recent fossils, or from seven to twenty-eight per cent.; and the last is the Pleiocene, with the most recent, or from forty to ninety-five per cent. Many of the great European capitals are built in countries formed of these rocks. Round London they consist of various clays, sands, and sandstones, with an immense variety of petrifactions, including shells, remains of tortoises, crocodiles, crustaceous animals, with plants resembling the date, Areca palm, and other tropical trees. Near Paris, again, they are composed of clay, limestone, gypsum, sand, and sandstone variously arranged. They are supposed to have been deposited in a gulf of the ancient ocean, full of salt water on the north-west, whilst on the south and east its waters were rendered fresh by the influx of land-streams. In Sicily this formation contains masses

of salt, sulphur, and gypsum, probably connected with the active volcanoes still found in that island; in other places, much brown coal, used as fuel, but inferior to that of the older formations, and on the shores of the Baltic, amber, supposed to be the resin of some tree, occur in tertiary rocks.

The last class of stratified rocks is the Alluvial, consisting of immense masses of clay, sand, and gravel, similar to the debris carried down by our present rivers. The older portion of these seems more general in its distribution, and has been named Diluvium, from its supposed connexion with great floods, especially the Deluge. The other, of more modern origin, is the Alluvium properly so called; but this division is not generally applicable. Part of these beds have been formed in the sea, and raised above it at a time comparatively recent, as those on the shores of the Firths of Forth and Clyde. Numerous erratic blocks, or travelled stones as they are called, are found in connexion with this formation. Near Edinburgh are many of these, of large size, rounded and water-worn, which are supposed to have come from the Highlands, where rocks agreeing with them in mineral character abound; and the great plain of Northern Europe, south of the Baltic, is covered with similar fragments, one of which weighed 15,000 cwts., derived from the mountains of Sweden and Finland. In these formations, the diamond, zircon, sapphire, spinelle ruby, and other precious stones, are found. Much gold and platina is procured from similar deposits, both in Brazil and the Ural Mountains. Some curious fossil animals also occur, the more interesting as they are only recently extinct. Of this kind is the Megatherium of South America (Fig 76), and

Fig. 76.

the Mammoth, a kind of elephant, whose tusks, the ivory from which is preferred to that of the living elephant, are so abund-dant in Siberia as to form an article of commerce, a ship being every year freighted with them. In the end of last century one of these animals was found completely preserved in the ice, its

flesh being still so fresh that the natives fed their dogs with it. The skull alone weighed 500 lbs., and the animal seems to have been covered with a thick reddish wool, and hence probably lived in a cold climate. Very recently, another, whose skin has been stuffed for one of the Russian museums, has been found in the same country.

Werner's first class of Primary Rocks are now considered to be beds belonging to some of the formations just described, which have been altered by heat. They contain no fossils, these having been destroyed in the changes they have undergone, and usually consist of a certain number of minerals arranged in definite forms. Among the more important varieties are Gneiss, a compound of quartz, mica, and felspar in various proportions, and sometimes with the addition of other minerals. Many valuable metallic ores are found in this rock, as some of the richest iron and copper mines of Sweden. One of the most remarkable of the former is the mountain of Gellivara, 1800 feet high, consisting entirely of iron ore. The copper mines, also, in this rock are the richest in that country. Mica slate consists of quartz and mica, the latter in such abundant layers as to give the rock a slaty structure. Both it and the former are frequently very curiously bent and contorted. It is often thickly strewed with garnets, and diamonds have recently been found in it in Brazil. Quartz rock consists almost entirely of this mineral, but often contains fragments of others. Clay slate also occurs, though principally near the transition rocks. Limestone, of a fine granular texture, or marble as it is called, is common; its usual colour being white, gray, or yellow, but often striped or clouded with green or red. The fine marble of Carrara is of this kind, but is believed to have been originally one of the oolite or even chalk beds. When much mixed with magnesia, this rock is named a Dolomite, likewise thought to be the result of igneous action.

The cause of all these changes, and of the various disturbances and breaking up of the strata, is supposed to be the Massive or Unstratified Rocks, to which an igneous origin is ascribed. They are conceived to have been rendered fluid by heat in the interior of the earth, and at last to have forced their way among the strata, or issued forth on the surface, like our present lava currents, their representatives in modern times. They have thus raised up the rocks which were above them into mountains, or where they reached the surface have themselves formed these elevations. Granite, a compound of quartz, mica, and felspar, is one of the most extensive, and it is believed oldest of these. It forms large masses of irregular shape on the surface; is found below gneiss and the other primary strata, or penetrates them

in veins and beds. The tin-mines of Cornwall are principally in this rock, through which the ore is either irregularly dispersed or collected in veins. The emerald, chrysoberyl, corundum, sapphire, and beryl, are found in it; the latter in Scotland, along with the brown rock-crystal or Cairngorm stones. Felspar porphyry, principally composed of the mineral whence it takes its name, is also a common igneous rock, especially among transition strata. Some varieties of it take a fine polish, and both in ancient and modern times have been cut into vases and other ornamental articles. Serpentine, named from its varied stripes and spots of yellow, red, green, and black, is less abundant, but also valued as an ornamental stone. The trap-rocks, named from the stair-like form of the hills composed of them, are common in most secondary formations, as round Edinburgh, where Arthur Seat and Salisbury Crag consist of them (Fig 77).

Fig. 77.

Basalt, remarkable for dividing into pillars of an irregular prismatic form, is well known in the Giants' Causeway, Fingal's Cave, and in the hills above mentioned. Trachyte is a felspar rock of a gray or reddish colour, and seems intermediate between these and the products of modern volcanoes. These are lava, a dark-red, brown, or black rock, sometimes compact, sometimes vitreous or glassy, when it is named Obsidian, or volcanic glass; at others, scoriaceous, like the slag from an iron furnace. Pumice is a light gray rock full of minute cavities, which render it so light as to float on water.

Veins, particularly those that contain metallic ores worth the working, present many interesting phenomena. They seem to have originated in cracks or fissures in the other rocks, which have been filled with minerals of various kinds. These are often arranged in parallel layers, following each other in the same order on both sides of the vein. The nature of their contents seems to depend on that of the rocks in which they occur, and the metals they contain frequently change in passing from one formation to another, as in Cornwall, where those filled with tin in the granite, yield copper in the slate. They are generally highly inclined, or sink nearly perpendicular into the earth, and some of them have been followed to a great depth. Their

breadth is seldom above a few feet, but many have been traced several miles in length. Those filled with trap-rocks are often named dikes; and though only a few feet or yards broad, have in some cases been traced twenty or thirty miles. The veins that contain metal are found in general near igneous rocks, and certain ores accompany particular varieties of these. Thus, copper occurs principally near greenstone, serpentine, or sienite, a variety of granite with hornblende instead of mica; gold and platinum in serpentine, porphyry, or the neighbouring strata; tin, silver, and mercury, often near granite; and iron ores near trap and hornblende rocks. Some ores are also frequently found united, as those of lead with silver or zinc, tin with copper, and gold with platinum and iron.

In considering the manner in which rocks have been formed, our best guide is the observation of those changes which nature is at present effecting on the earth. The atmosphere, by its chemical affinity with the various elements of rocks, destroys some of them with great rapidity. Those of a compound nature are most readily affected, and hence granite is often a less durable material than some varieties of sandstone, consisting of pure quartz. Rain and moisture effect the same purpose, especially by the expansion which water undergoes in freezing. When collected into streams and rivers, water is a still more destructive agent, wearing the hardest rocks, and sweeping the detached fragments down into the ocean. These fragments are themselves agents of change, grinding and rubbing down each other, and the bed of the stream over which they pass. In the ocean, again, the tides, currents, and waves, all produce motion, and effect many changes on its bed and shores. But nothing in nature is lost, and this debris of old strata forms the material of new ones, spread out at the bottom of the ocean, to be in future ages raised up into mountains, islands, and continents. Volcanoes and earthquakes also are powerful causes of change. The former have in some instances produced considerable mountains in a single eruption, or thrown out a mass of lava covering many square miles of country with a sheet of molten stone. The fate of Herculaneum and Pompeii, thus buried by lava from Vesuvius, is well known. Volcanic eruptions have also formed islands in the sea, some of which still continue; whilst others, as Graham's Island, formed in the Mediterranean in 1831 (Fig. 78), have again disappeared. Earthquakes likewise produce many changes which are not limited to countries where active volcanoes now exist. Thus of late years shocks have been repeatedly felt near Comrie, in Perthshire. In 1755, Lisbon was destroyed by an exceedingly violent earthquake, whose chief seat seems to have been below the Atlantic Ocean, as it was felt all round

Fig. 78.

its coasts in Europe, America, the West Indies, and Northern Africa, over nearly one-thirteenth of the earth's surface. During this convulsion the coast of Portugal sunk; but one in 1822 raised a hundred miles of the coast of Chili from three to four feet; and evidence of still greater elevation may be seen in many places. The coast of Sweden is now regularly rising in certain parts, and sinking in others, in consequence, as some suppose, of slight shocks of earthquakes. In our own country, also, the beds of sea-shells, found high above the water, and even on the tops of hills, prove the recent elevation of the land.

We have seen that some facts connected with the plants and animals preserved in rocks lead to the opinion that Northern Europe had at one time a warmer climate than it at present possesses. It is also observed that mines become warmer as they descend in the earth, and that Artesian wells have a higher temperature in proportion to the depth from whence they draw their waters. Numerous observations of this kind, in various parts of the world, show that the temperature of the earth's crust regularly increases with the depth, at the rate of about one degree of Fahrenheit in fifty or sixty feet. The earth also has nearly that form which a fluid mass rotating on its axis with the same velocity would assume. From these facts it has been thought probable that the earth at some former period possessed so high a temperature as to be reduced to the fluid or even gaseous state; that it cooled gradually, and formed a solid crust on the exterior; that the higher temperature of the surface, in former times, resulted from the remains of its original heat; and that the centre is still a molten mass, and volcanoes and earthquakes are occasioned by changes in this internal ocean of lava, as it may be called. Many difficulties, however, attach to this hypothesis, and the facts on which it depends admit of other explanations. Thus the higher temperature of the earth in former times may be accounted for

by changes in the distribution of land and sea; and the origin of volcanoes has been ascribed to chemical action going on in the interior of the earth. These, however, seem speculations concerning which no certainty can be attained, and do not interfere with the practical results of the science. The importance of these to the miner in his search after valuable ores of the metals, and those stores of fuel in which our own island is peculiarly rich, has long been acknowledged; and its connexion with agriculture and other useful arts is becoming every day more apparent. Independent of all this, however, the history of that earth which the human race has inhabited for so many generations, and which has formed the theatre of those great and ennobling deeds which history relates; the various revolutions it has undergone in ages long prior to the formation of man, by which its continents and islands have been prepared for his dwelling-place, and those mineral stores accumulated in its rocks which were required for his wants; and the records of the various tribes of plants and animals which have successively flourished on its surface;—all form a subject of the deepest interest to the reflecting mind, and one which it should require no external advantages to induce us to study.

Section III.—PHYSICAL GEOGRAPHY.

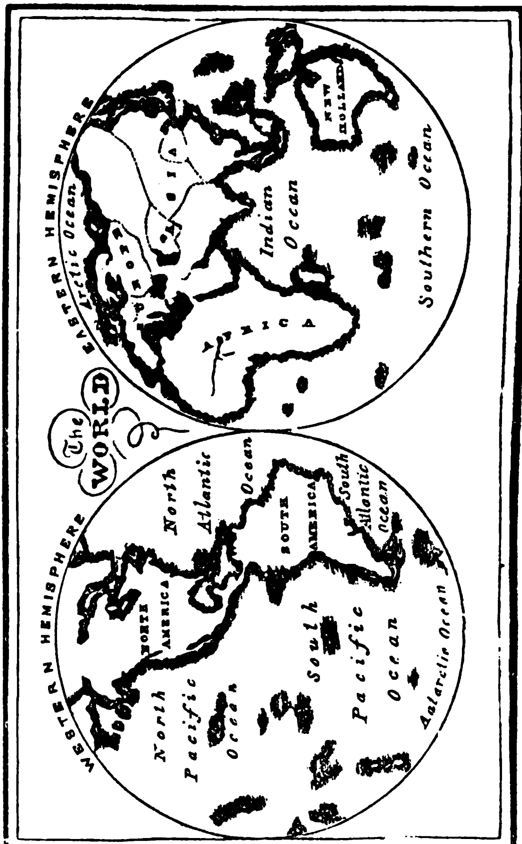
The science of Geology, properly so called, concerns itself especially with the phenomena of the crust of the earth, and the internal arrangement of the various materials of which it consists. Physical Geography, on the other hand, considers the external form of the earth's surface, and the manner in which its different parts are arranged. It treats of the distribution of the land and water on the globe, the different phenomena of these and of the atmosphere, and of the manner in which the various classes of organized beings are distributed over the earth, and the causes which have regulated this distribution. In the former part it encroaches in some measure on the field of Geology and Astronomy, as in the latter on that of Botany and Zoology.

The form and magnitude of the earth have engaged the attention of philosophers from an early period of science, and the attempts of the Grecian astronomers to determine them had more success than might have been expected, when we consider their imperfect instruments and methods of observation. It is only very recently that the true figure of the earth has been determined with accuracy, and even yet much remains to be

done in this respect. The earth is not a perfect sphere, as was formerly supposed, but rises up round the equator, and is flattened or compressed at the poles. Such a figure is named a spheroid and the difference of its longest and shortest radii, or the lines from the centre to the equator and to the poles, is named the compression. The amount of this may be found in two ways—the one by measuring a portion of the earth's surface corresponding to a degree of latitude in different places, and comparing the length of these. This has been done in various countries, from the equator in Peru to the arctic circle in Sweden, and the result is, that they increase towards the north, proving that the earth is flattened there. Another method is by means of the pendulum, whose vibrations vary in quickness both with its length and with the force of gravity acting on it. It is found that a pendulum of a given length makes fewer vibrations in a minute at the equator than it does farther north; and hence is less powerfully acted on by gravity, or is farther removed from the centre of the earth. By these means it has been calculated that the polar radius of the earth is rather more than thirteen miles shorter than the equatorial, and that the surface of the earth is so much nearer the centre at the poles than under the line. It also appears that this is nearly the form which the earth, supposing all its parts soft and yielding, would require to assume in order that water might remain at rest on the surface. The reason of this is, that the earth rotating with most velocity at the equator, the force of attraction there is diminished; and unless the surface was higher, all the water in the ocean would flow thither. The various mountains and valleys on the earth do not interfere much with its regular form, as they are very small compared with its diameter. The highest mountains are less than an 800th part of its radius, and do not exceed the irregularities on the surface of a common terrestrial globe. The mean radius of the earth is 3956 miles, its surface 196 million of square miles, and its solid contents 259 thousand million of miles cube. Its mean density has also been found to be about five times that of water, or about twice that of the substances composing that portion of its crust known to us.

The globe, considered as a whole, forms three great divisions,—the land, the water, and the atmosphere. The last of these invests the whole globe, whilst the two others divide its surface between them in a very irregular manner, as is seen from the map of the world (Fig. 79). The continents, or large connected masses of land, are situated much nearer the north than the south pole; so that if the earth be divided into two equal parts by the equator, more than three-fourths of the land is in the northern hemisphere. If, however, it is divided into two portions, of

Fig. 79.



which London forms the centre of one, that will contain nearly all the land on the globe, except New Holland and a small corner of South America. Even as figured in the map, it will be seen that the eastern hemisphere contains far more land than the western. If the whole surface of the earth be regarded as forming thirty-seven equal parts, ten of these consist of land, and the remaining twenty-seven of water. It was once thought

that there must be a large continent near the south pole to balance the mass of land in the north, but this is now ascertained to be unnecessary, as there may be as much land there, though not raised above the level of the water.

It is usual to divide the land into continents, comprising the large connected portions, and islands, the smaller. Properly speaking there are only two continents, but these are regarded as divided into several, often named quarters of the globe. In the western continent of North and South America the greatest extent of land is from pole to pole, whereas in the eastern hemisphere it is from south-west to north-east. The longest straight line on the former is nine thousand, on the latter, eleven thousand miles. In both continents most of the peninsulas run towards the south, as South America, California, Florida, and Greenland, in the new world; Sweden, Spain, Italy, Greece, Africa, Arabia, Hindostan, and Malacca, in the old. If Africa be supposed connected with Europe, and New Holland with Asia, the land will form three divisions, each consisting of a northern and southern portion, joined by a narrow isthmus or range of islands, and having nearly a similar shape. In regard to their internal structure, Africa seems the worst adapted for the habitation of man. It consists of a larger unbroken mass of land than any of the others, has no gulfs or deep bays, and few large navigable rivers; so that the interior is almost inaccessible from the coast, and few advantages are offered to commerce. Its sandy deserts have also put a check to internal intercourse, and in all ages its interior has been unknown and unvisited by strangers. Asia is more divided by gulfs and bays; and its numerous large rivers form lines of communication from the coast to the interior. Here, however, lofty mountain-chains and extensive deserts impose a considerable check on internal communication. Europe is still more favourably situated in regard both to rivers and connexion with the seacoast; and with the similar part of Asia, bordering on the Mediterranean, has at all times formed the seat of the highest degree of civilisation. America also, both on its eastern and western coasts, has many gulfs and bays, whilst its large rivers form natural canals throughout almost the whole breadth of the land, and is thus well adapted both for internal and external commerce.

Islands resemble continents on a small scale, and with fewer distinct parts. Small islands are often arranged in groups, which correspond with the direction of the mountain-chains in the neighbouring large ones or on the continent. These islands are regarded as the summits of the mountain-chain continued below the sea, others are formed by volcanoes, and a third class by portions of land separated from the larger masses in their vici-

nity. The sea often throws up sand-banks, particularly near the mouths of rivers, which at last become islands covered with vegetation and inhabited. Coral reefs, built up from a great depth by the minute coral insect, also give rise to islands. These have frequently a form approaching to the circular, with an opening on one side, and a sheet of water within; whilst others form long reefs or barriers along the shores, or even enclose an island in their circuit.

Continents and islands have their surfaces diversified by plains, valleys, hills, and mountains. Plains may be regarded as the natural state of the earth's surface, and mountains as the deviation from it. Plains are often of vast extent, as that in the North of Europe, extending, with very few hills or considerable inequalities, from Holland, throughout Germany and Russia, to the Ural Mountains, beyond which it again extends over most of Asia north of the Altai Mountains. When much raised above the sea, plains are named table-lands, of which those of Quito, in the Andes, 12,000 feet high, are among the most remarkable. Mexico is also a table-land; and in the centre of Asia there is another of still greater extent, partly covered by the sandy desert of Cobi or Shamo, and bounded by the Altai Mountains on the north, and on the south by the Himalaya and connected chains. Plains have received different names from the kind of vegetation they support. Thus, in Europe, some are called heaths, from the abundance of plants of this nature, that of Luneburg extending to six thousand square miles, with a few woods and lakes interspersed. In Russia the continuation of the same plain is named the steppes, and is partly covered with rich pastures, partly with woods, and partly with barren sands, containing lakes and pools of salt-water. In Northern Asia the same appearance is presented in the country inhabited by the Tartars and other wandering tribes. In America they are named savannahs and prairies; some with small shrubs and bushes, some only with grass and no water, and others in the river-valleys with a very luxuriant herbage. Some of them contain many hundred thousand acres, and are fed on by innumerable herds of deer and bisons. In South America they are named llanos, and are so flat that in 300 square miles not an eminence a foot high is seen. In the dry season they are covered with dust and withered grass, but in the rainy period of the year they are clothed with the most beautiful and luxuriant verdure. The pampas of La Plata are similar, but in some parts sandy, with patches of saline plants. On the Maranon are large forest-covered plains, or selvas, as they are named. Such extensive plains do not seem favourable to the progress of civilisation, being generally in-

habited by wandering bands of herdsmen or hunters, whose incursions are extremely injurious to the more settled nations in their vicinity.

Deserts are not always, though often, plains. In Northern Europe there are many square miles of sandy plains fully entitled to this name. The great Sahara of Northern Africa, covered with waves of moving sand, is a still more remarkable example. It is seldom refreshed by a shower of rain, and, for most of the year, a hot dry air, as of a furnace, hangs over the waste of arid sand. A similar zone, with a few exceptions, extends over the whole ancient continent. In Egypt it is hardly interrupted by the Nile; in Arabia only the coasts and a few valleys show any traces of vegetation; and the fertile basin of the Tigris and Euphrates scarcely breaks the burning sands and wastes covered with salt, gypsum, and mineral springs, which extend towards Syria and Persia. In the latter country nearly a third of the surface is a salt desert; and farther east, in Tartary, half the central plain of 100,000 leagues is arid waste. In the old world it is computed that a space equal to the whole of Europe, or forty-four times the size of Great Britain, is covered by barren deserts. These deserts seem to arise from the manner in which the rains are distributed on the earth.

Valleys depend on mountains, by which they are formed, and fall more properly to be treated after them. Some hills and mountains are isolated, or stand alone in the midst of a plain, but such elevations are rare, and mostly of volcanic origin. In general, several are conjoined into groups or chains, whose breadth is small compared to their length. A chain of mountains may be curved or in a straight line; but both are generally somewhat irregular, many small chains, broken and interrupted, being frequently combined in one great chain. The central ridge is often the highest, with lower ones on the sides, but the reverse sometimes takes place. Mountains also have generally one side steeper than the other, as is well seen in the Andes, where a long gently falling plain reaches from them to the Atlantic, whilst they sink precipitously to the Pacific. In Great Britain many hills have their steepest acclivity to the west. Their summits also vary from a peak or sharp ridge to a broad plateau or table-land. Their forms depend much on the rocks of which they consist, so that an experienced geologist can, in many cases, tell the formation to which they belong from their aspect even at a distance. Mountains are divided by valleys, of which two kinds ought to be distinguished. Those which are parallel, or run in the same direction with the mountains between the ridges, are named longitudinal valleys; and those at right angles to these, cutting across the ridges, are named

transverse. The first are of course the longest; they are also in general the widest, and their sides slope most gradually. The others are often deep and narrow, with precipitous banks and overhanging rocks. Valleys of both kinds are common in almost every mountain-district, and the distinction between them is of much importance.

How valleys have originated is an interesting question in Physical Geography. Some have referred them entirely to the erosion of the present rivers, some to marine currents before and during the rise of the land from the ocean, and others to the natural inequalities produced during the elevation of the rocks forming mountains. The cause assigned by the last has had most influence, as many geological facts show, especially where a river rises on one side of a mountain-ridge and crosses it in a narrow transverse valley. This is also shown where valleys turn suddenly at right angles to their former direction, which was not likely to occur in the course either of rivers or currents. A valley like that of the Caledonian Canal, portions of which, as Loch Ness, are deeper than any part of the neighbouring ocean, also show the insufficiency of rivers or currents for their formation. Valleys, however, have been formed in all these ways, and one of them has often greatly modified the forms of those originating in another.

Most mountains have probably been produced by eruptions of igneous rocks, which, however, do not appear in all of them. Granite, though more rarely than is generally supposed, porphyry, and trap rocks, often compose the highest part of hills. Still more evidently connected with igneous action are volcanoes, either such as are now in activity, or have been since the surface of the earth assumed its present form. Such mountains are generally conical in form, and on the top have a deep hollow or crater, from which smoke, ashes, and melted matters named lava, are ejected. The smoke is a very frequent occurrence, but eruptions of solid matters are more rare, and only occur at irregular and often long intervals. Stromboli, a small volcano on the Lipari Islands, is in almost constant activity; the eruptions of Vesuvius only occur after years of repose, and those of Etna after still longer periods. From these large mountains the lava more frequently escapes through the sides than at the summit. Aqueous vapours, sulphurated hydrogen gas often infecting the air for miles around, sulphur, sal ammoniac, common salt, and water, in some American volcanoes accompanied by fishes, which seem to have lived in cavities of the mountains, are also ejected. One of the most violent eruptions in recent times was that in 1815, from Tomboro, in the Indian Archipelago. The shaking of the ground was felt, and the report of

the explosions heard for a thousand miles around, while showers of ashes several inches deep fell on Java, 300 miles distant. On the island itself some thousands of the inhabitants were destroyed by its fury. During one eruption in Iceland, the lava covered several hundred square miles of ground, and continued warm

Fig. 80.

Mount Hecla, Iceland.

and smoking for years. Mud volcanoes are named from their ejecting masses of earth and water, and others seem only to give vent to air or vapour. The number of volcanoes is very great, having some years ago been reckoned at two hundred, of which more than a half were in America and its islands. This number should be increased at least by one-half, many having recently been discovered by travellers. Though volcanoes sometimes stand alone, they more frequently form groups, either linear or circular. An immense chain of them seems to surround the shores of the Pacific Ocean, being found in New Zealand, the New Hebrides, Java, Sumatra, the Philippines, and Japan, on the Asiatic side; and in Mexico, Guatemala, and the whole chain of the Andes, on the American. Vesuvius is the only one now acting on the European continent, though there are several in the islands, and many extinct ones are known both in France and Germany. They were at one time thought only to occur in the vicinity of the sea, and consequently to be connected with the admission of its waters to the molten nucleus within. They are now known, however, to range throughout the whole of Central Mexico; and others have been observed in the interior of the Asiatic continent still farther from the ocean. Considerable bodies of water are, however, generally found in their vicinity, and seem in some way connected with their eruptions.

Section IV.—WATERS OF THE GLOBE.

The second great division of the earth's surface is that occupied by water. This is either fresh or salt,—the former comprehending most of that found on the land, the latter the ocean, with its various branches. Springs, the sources of rivers, draw their supplies from the atmosphere, the rain which falls on the high grounds being absorbed into the interior and again brought up to the surface. They generally break out where some fissure occurs in the strata, or a bed of clay or rock impervious to water interrupts their downward progress. Springs seem wholly derived from rain, and there is no reason to think that any are formed by water from the ocean raised to the surface by oozing through sand or narrow fissures, as has often been said. It has been found that the rain which falls in particular districts is more than sufficient to account for all their springs and rivers. Spring-water is seldom, if ever, pure, but contains various gaseous, saline, earthy, or metallic matters. Where these are so abundant as sensibly to affect the purity of the water, they form mineral springs. The most common substances are carbonic acid gas, which gives the water a pleasant acid taste; sulphurated hydrogen gas, easily known by its disagreeable smell, forming what are named sulphureous waters; salts of iron, forming chalybeate waters; and various salts, as the sulphates, muriates, and carbonates of lime, magnesia, and soda, forming the saline mineral waters. Their medicinal properties of course depend on the nature and amount of these ingredients. Some springs are warm or hot, their temperature rising from that of the atmosphere to the boiling point, and in the interior much higher, as is shown by the quantity of steam that escapes. The most celebrated hot spring is the Geyser, in Iceland, which throws out its waters to an immense height. Petrifying springs usually contain carbonate of lime, which they deposit on coming to the air, encrusting objects placed in them. These calcareous springs are very common in all countries, but those which deposit siliceous matter or flint are more rare.

Though the rain falls only at longer or shorter intervals, yet springs, especially those that rise deep in the earth, generally flow without intermission. This is caused by the water accumulating either in cavities or fissures among the rocks, whence it escapes slowly. Some springs are, however, intermittent—flowing for a period, and then ceasing. The manner in which this takes place has been explained in this way (Fig. 81). A is a cavity in a hill, gradually supplied by rain-water percolating

Fig. 81.

through the superior rocks, and communicating with the surface by the channel B C D. No water can escape from A till it rises high enough to run over at C, when the channel being filled acts like a syphon, and will drain the whole water in the cavity; the spring at D then stops until A is again filled to the proper level. If the supply of water is at all times nearly uniform, it is evident that the reservoir will fill and empty at regular intervals.

Artesian wells, named from the province of Artois in France, where they have been long in use, are explained in a similar manner. The rain which falls on the hills is absorbed among the rocks, and if the strata are unbroken, may flow between them to a great distance; and where, as is often the case, the beds fill a hollow and rise up all round its sides, much water will collect between them. When therefore a bore is formed through these rocks, till it reaches the reservoir, the water rises up in it, and, if its source is high enough, flows over on the surface. Such wells have been formed with much success near many large cities, which are generally situated in plains. The high temperature of the water, already noticed, has in some places been employed in baths and for other useful purposes.

The water from springs collects in hollows, and there forms brooks or rivulets, which unite into rivers. The whole country from which a river draws its supply of water is named its basin; and its various parts and valleys have a general inclination towards the river, and its mouth in the sea. It is wrong, how-

ever, to suppose, that river-basins are always bounded by hills, or that large rivers always rise in lofty mountains, as the reverse is often the case. Thus the Volga rises in a plain only a few hundred feet above the sea-level, and no hills even separate its waters from those that flow to the Baltic. Many rivers cross mountain-chains; but in general their courses follow the declivity of the land, and their length is determined by the distance of the ridges from the sea. Thus the high mountain-chains of America are near the west coast, and most of its large rivers flow to the east. In the old world, also, more of the large rivers flow east than west; and even in our own island this is the case —the Tay, Forth, and Tweed, in Scotland, with the Tyne, Humber, and Thames, in England, following this direction; whilst the Clyde and Severn are the only remarkable exceptions. The velocity of rivers depends on the declivity of their channels and the amount of water they contain, the latter being often more important than the former. Thus the Rhine, though a rapid stream, does not fall in much of its lower course a foot in a mile, and the mighty Amazon not twelve feet in the last 700 miles of its course, or about an inch in five miles. Cataracts or waterfalls usually occur where the channel of rivers is crossed by ledges of rocks, whose hardness has enabled them to resist the destructive effects of the water. In most very long rivers such falls are found, as those of Niagara, or of the Rhine at Schaffhausen. Some rivers are navigable almost to their sources, as the Volga, and the Shannon in Ireland; and others for a great part of their course, as the Mississippi to the falls of St Anthony, 1800 miles from its mouth.

Some rivers disappear during part of their course, as the Rhone below rocks, and the Guadiana in sands, whence, however, they again emerge. During rains, or at those times when the snow melts on the mountains round their sources, rivers become flooded; in tropical countries, where the rains are periodical, their inundations are so likewise, as in the Ganges and other rivers of India. The Nile owes its increase, so celebrated among the writers of antiquity, to the periodical rains in the interior. Other rivers, in temperate climates, are highest during the summer from the melting of the snow on the mountains. Most floods are, however, caused by violent rains, and are only temporary in duration, as in the rivers of our own country, when the small streams are always proportionally more swollen than the large rivers, from the rain over the whole basin falling more nearly at one time and being sooner collected. The Amazon river, flowing almost under the equator, is remarkable for its equal discharge of water, its tributaries on the north and south being in flood at opposite seasons of the year.

River-water is never pure, but contains more or less solid matter suspended in it. Small streams in flood contain about a sixtieth part of mud, and large rivers from a 200th to a 20,000th part. They thus carry down an immense mass of matter to the ocean: the Rhine, for example, nearly two million cubic yards every year; and the Yellow River, in China, enough every seventy days to form an island a mile square in the shallow sea into which it flows. Where they meet the tides this matter is deposited, and forms a bar or sand-bank, often very prejudicial to navigation. In many cases it fills up the sea near the mouth of the river, and forms a low marshy piece of land, which has been named a Delta, from its triangular shape resembling this letter in the Greek alphabet.

Lakes are formed where water collects in hollows, and are surrounded by land, as islands are by the ocean. Some, generally of small extent, have no streams running into or leaving them, and, when found on the summits of mountains, seem to be old volcanic craters. Others, frequently of similar origin, give rise to streams without receiving any, and are generally placed in elevated situations, as that on Monte Rotondo, in Corsica, 9000 feet above the sea. Many large rivers, as the Volga, take their rise in such lakes, in this case lying in a plain of small elevation. This river also ends in one of a third class, or those which have affluents, but no communication with the ocean. The Caspian is the largest of these, being about 700 miles long by 300 broad. Lake Aral, and many others near it, belong to the same class, together with the Dead Sea, in Palestine. It was formerly thought that these lakes communicated with the ocean below ground; but this cannot be the case, since the Caspian is about a hundred feet, and the Dead Sea thirteen hundred, below the sea-level. The water that flows into them must therefore be carried away by evaporation, which may be shown to be amply sufficient for this purpose. Most lakes, however, have streams flowing both into and from them, as the large lakes of North America, and most of those in our own country. The water of lakes, especially the latter class, is usually fresh; that of the third class, without affluents, is often salt. This is the nature of that of the Caspian and of the Dead Sea; and many small lakes near the former contain so much saline matter, that the salt is deposited in solid beds, and yields a great article of commerce. Lakes are formed principally by original depressions in the land, produced in the same manner as valleys, though it is evident that our present rivers could have no effect in hollowing them out. On the contrary, by the debris they bring down, they tend to fill up and obliterate lakes, and have turned many into level valleys. Where, however, a river enters a valley at the side, it

may form a lake, by raising an embankment across it with the sand and gravel carried down. Lake Cirknitz, in Illyria, is remarkable for the periodic disappearance of its waters, owing to the subterranean sources that supply it being cut off in very dry seasons.

The ocean, towards which all rivers tend, contains the largest portion of the waters on the globe. Its blue or green colour only appears from its great depth and extent, as its waters at a distance from the coast are equally transparent with those of the purest rivers. This colour passes through all the shades from deep ultramarine to olive-green. The ocean varies much in transparency in different parts, being most so in northern latitudes far from the shore. Light penetrates about sixty feet deep, though some writers affirm that the bottom may be seen 150 feet, and in the northern seas even 400 to 500 from the surface. The luminous or phosphorescent property of the sea is one of its most beautiful phenomena. At such times a ship seems sailing among waves of flashing fire, and the whole surface is covered with brilliant stars and masses of greenish light. This is owing either to animal matter diffused through the water, or to animalculæ, which emit a phosphorescent light when disturbed by the motion of the vessel. The depth of the ocean varies very much, but is not certainly known. The Atlantic between Europe and America is thought to be not very deep, though no bottom has been found with 300 fathoms. In the North Sea even 800 to 1200 fathoms failed to reach the bottom; and the Pacific is thought to be still deeper. The North Sea between Shetland and Norway is only from 80 to 140 fathoms, and becomes shallower towards the south, the deepest part of Dover Straits being only twenty-six fathoms. The Baltic is seldom above forty fathoms, but in a few places a hundred, whilst the Mediterranean between Spain and Italy is from five hundred to a thousand fathoms. The level of the ocean is thought to be every where the same, but to this there are some exceptions. Thus the Baltic, from the amount of fresh water it receives, is higher than the North Sea, the difference on the opposite sides of Jutland being about a foot. The Mediterranean is lower than all the surrounding seas, and strong currents run into it both from the Atlantic and Black Sea. This is owing to the great evaporation, which is three times more than all the water brought into it by rivers. On opposite sides of France the difference is stated at from three to six feet between it and the Atlantic; while the Red Sea at the Isthmus of Suez exceeds it in height by thirty-two feet. The Pacific is also three and a half feet above the waters of the Gulf of Mexico.

The saltness of the ocean has excited much curiosity in all

ages, and the causes of it are often inquired into. The question, however, ought to be reversed, and it should rather be asked, why springs and rivers are fresh, since probably there is a million times more salt than fresh water on the globe? The proportion of saline matter contained in sea-water varies considerably in different places, the Southern Ocean being salter than the Northern, and the Mediterranean than the ocean. In a thousand grains of water from the English Channel there are about twenty-seven of common salt (chloride of sodium) and six of salts of magnesium, with two grains of other substances, principally compounds of lime. The water of the Mediterranean has the same amount of common salt, above thirteen grains of salts of magnesia, and scarcely one grain of solid matters. On the African coast, where the great rivers, with much vegetable matter, mingle with the ocean, a large quantity of sulphurated hydrogen gas is produced, which is thought to cause the unhealthy nature of that coast. The temperature of the ocean also varies in different parts, being naturally higher near the equator, at least at the surface. The warmest part is, however, a few degrees north of the line. The temperature varies less than that of the air, as the cold water sinks, and the warm rises in its place; and the whole mass must be cooled before any great change can take place. From this sinking of the colder water, it follows that the temperature must be lower at the bottom than on the surface, and this is found to be generally the case. In the Caribbean Sea, Sabine found that the temperature fell 36° at the depth of 1000 fathoms. In Baffin's Bay, at about four thousand feet, the difference was only eight degrees. At great depths, however, the temperature varies little, and seems to become nearly stationary. In some parts of the ocean it appears even to rise as the depth increases; and Scoresby found it six or seven degrees warmer at the depth of from one to two hundred fathoms than on the surface in the Greenland Sea. In the Gulf Stream, between eighty and one hundred fathoms from the surface, the sounding-lead has been so heated that when drawn up it could scarcely be held in the hand.

The variations of temperature, combined with the rotation of the earth, are the principal causes of the currents in the ocean. The warm water at the tropics is naturally lighter than the colder water towards the poles, and hence has a tendency to rise above and flow over it. The cold polar water has in the same manner a tendency to flow towards the equator below, and thus supply the place of the warm water that has run towards the poles. In this way, were the earth at rest, there would be established an upper current of warm water

from the line towards the poles, and a lower current of cold water in the opposite direction. In consequence, however, of the rotation of the earth, and its surface moving faster at the equator than to the north or south of it, the water from the poles has a slower motion than that part of the earth at which it successively arrives; and hence is left behind, or seems to run in an opposite direction, from east to west. For the same reason, the surface-water, in flowing north or south from the equator, will have a tendency to run to the east. From these causes almost all the currents in the ocean seem to arise; and their deviations may mostly be explained by the form of the land they encounter. One of the most remarkable currents is that which runs from the coast of Africa towards America under the equator, and, passing down through the Caribbean Sea and the Gulf of Mexico, flows out between Cuba and Florida, in what is named the Gulf Stream, and, crossing the Atlantic by the Azores, washes the western shores of Europe. Part of it again joins the original current, according to Humboldt, completing this majestic circuit in about three years.

Section V.—ATMOSPHERE.

The mechanical properties of aerial bodies have been already considered in treating of Pneumatics. These, as applied to explain the phenomena of the atmosphere, constitute that branch of Natural History named Meteorology. The atmosphere, meaning the sphere of vapours, surrounds the whole earth, and participates in all its motions both of revolution and rotation. It consists principally of the two gases, oxygen and nitrogen, in the proportion of one volume of the former to four of the latter. With these are generally combined one part in a thousand by weight of carbonic acid, and a variable amount of aqueous vapour. The respiration of animals and combustion constantly deprive the atmosphere of a part of its oxygen, which is converted into carbonic acid; but this is again decomposed by the vegetable world, and no sensible change takes place in its composition. The weight of the atmosphere is equal to that of a sea of water 33½ feet deep covering the earth, or scarcely a millionth part of the weight of the whole globe. Being an elastic fluid, expanding as it ascends and the pressure above becomes less, its height cannot be determined, but probably is from fifty to a hundred miles.

The atmosphere derives its heat principally, or we may say entirely, from the sun. The position of the earth, therefore,

in respect to this luminary, regulates the degree of temperature, which in this country varies in a daily and annual period. Hence the temperature of a place is found by taking the mean or average of these periods, and, as one year differs from another, the mean also of several years. Places near the equator, having the sun more immediately over them, enjoy more heat than those on the north or south, and, at the same time, a greater equality of seasons. The elevation above the sea also affects the temperature, the air becoming colder as we ascend. In northern latitudes the ocean has a higher temperature than the land, to which it imparts a portion of its heat; and hence places near it, particularly on the west side of the continents, are warmer than those in the interior. All these things affect the mean temperature of a place, and thus it cannot be discovered merely by its distance from the equator. To show how the heat is distributed on the globe, Humboldt drew lines on a map, connecting all the places which had an equal temperature throughout the year. These, named isothermal lines, from a Greek word meaning "equal heat," show that the west coast of Europe is much warmer than the United States in the same latitude, and also than the interior of Europe or Asia. Thus the mean temperature of London differs little from that of Paris, though 2½° north of it; and is much above that of Vienna, which is still farther south. Philadelphia and New York, again, though eleven degrees of latitude farther south, are only four or five degrees warmer than London, and much colder than Rome, which is nearly at the same distance from the equator. Places near the sea have also a much milder climate than those in the interior; and hence our summers are not so warm and our winters not so cold as on the continent of Europe, and much less so than in America. Even in the northern parts of this island, cattle can remain without protection, and men pursue their usual occupations in the open air during the whole year, which is not the case in these other countries even farther south.

The cold increasing as we ascend, there is a certain height on lofty mountains where the snow never melts. This is named the snow-line, and its elevation varies with the temperature of the low grounds, and also with the amount of snow that falls. At the equator it is estimated at 17,000 feet; at 45° north latitude, 9000 feet; at 60°, about 6000 feet; and at 75° it sinks to the level of the sea. In Peru, south of the line, the limit of perpetual snow rises to above 17,000 feet; on the Pyrenees it is about 9000; and on the Alps a few hundred feet less. The higher parts of the mountains are covered with snow in fine grains, and it is only lower down that it begins to form ice or glaciers. The latter are vast fields of ice, generally much

divided by fissures, and very uneven on the surface, which accumulate in many valleys among lofty mountains, especially the Alps. They are in constant motion downwards, and descend far below the line of perpetual snow, in cold seasons often encroaching on the cultivated fields. This motion is slow and gradual, differing from that of the avalanches, in which a portion of the glacier is detached, and rolls down with great violence. During winter, in Switzerland, there are avalanches of snow, which rolls down in huge masses, burying houses and even villages. Many large rivers take their rise in these glaciers, the water from which has generally a whitish milky colour.

The motions of the atmosphere, or winds, seem to arise principally from changes of temperature destroying its equilibrium. Heated air becomes lighter and ascends; and hence when any portion of the earth's surface is more warmed than those around, the air there rises up and flows over above, whilst the cold air presses in below. In consequence of this, currents are produced in the atmosphere, blowing at the surface of the earth from the colder to the warmer regions, and above in the opposite direction. These are the causes of winds, which are either regular or irregular. The regular winds are either constant, blowing always in one direction, or periodical, changing at fixed seasons. The constant or permanent winds are those named the Trades, which blow on both sides of the equator, from north-east in the northern, and from south-east in the southern hemisphere. They are caused by the ascent of the heated air over the tropics, to supply which that on the north and south flows towards the line; and, being left behind by the greater velocity with which the earth rotates there, appear to form winds blowing from the north-east and south-east. They extend to about 30° north and south of the line, varying, however, with the position of the sun; and their name is derived from the great facility they give to navigation. In the Indian Ocean, periodical winds, named Monsoons, prevail. They are most regular in the Java Sea and east to New Guinea, and blow in opposite directions at different seasons of the year. On the north of the equator they blow from the south-west from April to October, and from the north-east during the other half of the year. On the south of the equator they blow from the south-east during the former, and from the north-west during the latter; seldom, however, extending beyond 10° of south latitude, where the regular south-east trade-wind begins to prevail. They are supposed to arise from the action of the sun on the land in that quarter, which, being much warmed during the summer, attracts the wind towards it, and are thus a mere modification of the trade-winds. In the same manner are produced the

land and sea breezes, found on the coasts of all hot countries, which during the day, when the land is warmest, blow from the sea towards it, and at night, when the sea has the higher temperature, in the opposite direction. Similar winds also prevail near mountains and on the shores of lakes, changing their direction with the changes in the temperature of the surface of the ground. North or south of 30° the winds are very irregular, though those from the west seem to prevail. This is especially true over the ocean; and is well shown by the fact, that the average voyage in the packets from Liverpool to New York was forty days, whilst that returning was only twenty-three. Even these changeable winds have been discovered to be governed by certain general laws, and it is probable that they will be found far more regular than has been supposed.

The velocity of the wind far surpasses that of rivers or sea-currents. A gentle wind blows four or five miles an hour, increases in a brisk gale to ten or fifteen, and at fifty becomes a storm, while a hurricane proceeds with a velocity of more than a hundred miles an hour. Hurricanes are most common near the tropics, and in the vicinity of land or islands, as, for example, in the West Indies. They are now ascertained to be all whirlwinds, the air whirling round a centre, which itself is moving with great rapidity in a particular direction. Hence it is generally found that at any place which they visit, the wind first blows violently from one point, and then, after a short calm, from the opposite. They produce the most frightful devastation along their track, rooting up trees and levelling houses with the ground. Water-spouts seem to be formed by clouds entangled in the centre of such whirlwinds, and are most common at sea.

Evaporation is constantly going on at the surface of the earth, and vapour rising into the atmosphere. But the amount of moisture which the air can contain varying with the temperature, when the latter falls, the water is condensed, forming clouds and rain. When warm moist air ascends into the cold parts of the atmosphere, or is mixed with cold air, it can no longer retain the vapour in solution. This therefore condenses into small globules, which, being extremely light, float in the atmosphere, forming clouds, or, collecting into larger drops, fall as rain, hail, or snow. The evaporation is most abundant in the torrid zone, where it is equal to a hundred inches of water in the year, whereas in the temperate zone it is reckoned at thirty-seven inches. More rain also falls in the warmer regions, but on fewer days, and hence must be far more violent. Thus, at St Domingo, as much rain falls in the year as, if all collected, would measure 120 inches deep; at Calcutta, from seventy to seventy-

five inches; at Rome, thirty-six inches; at London, twenty-three; and at St Petersburg only sixteen inches. The west coasts, both of continents and islands, are, however, wetter than those on the east, especially near mountains. Thus, at Kendal, in Westmoreland, sixty inches fall every year; and at Bergen, in Norway, eighty-eight inches; whereas in Sweden the average is only eighteen inches, or about one-fifth. Rain is heavier in general on mountains; but more falls at the foot than the top of a high tower, the drops collecting moisture and increasing in size as they descend. Some parts of the earth have little or no rain, as that zone of sandy desert which extends across the old world a little to the north of the tropic. Egypt is contained in this zone, and is very seldom watered by a shower, though this occurs more frequently now than in former times. In the torrid zone the rain falls principally during the summer months, or at the time when the sun is directly over head; and the year there is divided into two seasons, the wet and the dry.

Snow is formed when the moisture freezes as it condenses, and falls to the ground in flakes. These exhibit crystals, arranged in regular forms, of which there are a very great variety. Hail consists of a grain of compact snow covered with a crust of ice, and falls chiefly in the warmest time of the day and year. It often extends in narrow tracks many miles long, and in France and Germany occasions much injury to the districts where it prevails. It is rare either in the torrid or frigid zone, and the manner of its formation has given rise to much difference of opinion. Dew is another form of aqueous deposition from the atmosphere. It principally falls in clear, calm nights, when the surface of the earth, much cooled by radiation, condenses the moisture in the air in contact with it. Hence also it collects most abundantly on grass or other plants which from the amount of surface exposed readily part with their heat, whilst none will be found on stones or the naked earth. When it freezes hoar-frost is formed, and hence clear nights, in which much dew falls, are always cold and very hurtful to vegetation. For the same reason, low-lying and apparently well-sheltered spots are usually most liable to have their crops injured by night frosts.

Fiery meteors seem to depend principally on electricity, though many of them are not yet fully explained. Lightning and thunder have been already noticed, and are the most common of these phenomena. The St Elmo's fire is seen attached to pointed objects during thunder-storms, or when the atmosphere is highly electrical. Some fireballs have a similar origin, but others seem to be of a different nature; and shooting stars are now thought, in many cases at least, to be beyond the limits of

the atmosphere. The aurora borealis, or northern lights, is seldom seen except in high latitudes, and is closely connected with the magnetic condition of the earth. This is shown by its always appearing in that part of the heavens to which the needle points, and by the disturbance it causes in this even at places where the luminous appearances are invisible. In the regions round the south pole a similar appearance is observed, and is there named the southern aurora. The rainbow, as already mentioned, is produced by the light refracted and reflected from small drops of rain. Double suns and mock suns are also occasioned by vapours in the atmosphere reflecting the light in particular ways. The mirage of the African deserts, the fata morgana of the Italians, arises from the heat of the sun changing the refracting power of the air. In the polar seas many curious phenomena are thus produced.

Section VI.—BOTANY.

Botany, a term derived from a Greek word signifying any kind of grass or herb, is the science that treats of the nature of plants, and describes their relations and uses. Plants possess a certain degree or kind of life inferior to that of animals; they are also organized but with a less intimate connexion in their parts, and show some signs of irritability, as in the motions of the sensitive plants. They are also highly sensible of the effects of light and heat, turning their leaves so that it may fall direct upon them, and closing or unfolding their flowers with the presence or absence of the sun. Their roots also extend a great distance in search of moisture, and seem in many cases to have an instinctive knowledge of the direction in which it may be found. Structural and Physiological Botany treats of the structure, internal or external, of plants, and of the laws and functions of their various organs. Descriptive Botany explains the language made use of in describing plants, so that we may know their character with certainty, and be enabled to recognise them by the names given to them in Systematic Botany, in which the vegetable world is arranged as one harmonious whole. Plants are formed of various tissues, especially the cellular, consisting of little bladders or vesicles compressed into lengthened angular forms. With this is mixed fibrous tissue, consisting of tubes of different lengths, and the vascular tissue, resembling transparent threads twisted into spiral vessels. Through these circulate the various juices that nourish the plant and enable it to grow.

The different parts of which a plant consists are in general familiar to all, and are well seen in the common heart's-ease, represented in Fig. 82. These consist of the stem (*a*), of a green

Fig. 82.

colour, to which the roots (*b*) are attached. It also gives rise to (*c c*) the leaves, at the base of each of which are two similar bodies (*d d*) named stipules. These form the organs of vegetation, by which the plant itself lives and grows. But besides these there are other organs of fructification, which produce fruit or seeds by which the species are multiplied and continued. These form the flower, supported on a stalk or peduncle springing from (*e*) the axil of the leaf. The two small scales or leaves

on this stalk (*ff*) are named bracts, whilst the green leaves (*g*), forming part of the flower, are named sepals, and collectively the calyx or cup. Within this are other coloured leaves (*h*) named petals, forming the corolla, which again enclose other parts (*i k*) to be afterwards described.

The root by which the plant is fixed to and derives its nourishment from the ground, consists especially of fibres, which in some cases spring from a central body, as in the turnip or carrot. Roots absorb moisture, and the other substances on which the plant feeds, principally by the extremities of these fibres. As the soil in which they first grew is exhausted, the roots increase in length, and seek for nourishment at a distance. They extend principally in a horizontal direction near the surface, where they come more readily into contact with atmospheric agents. Some plants, however, will continue to grow when deprived of all communication with the ground; and the parasitic tribes, like the mistletoe, fix their roots in other plants, and seem to extract nourishment from them. All the parts of a plant found below ground are not, however, to be considered as the root. Thus the potato is not a root, but what is called a tuber, or an underground stem, the long fibres attached to it being the true roots. So also the root of the onion or lily is not the bulb, but the long threads that depend from it.

The stem of a plant, when cut through, generally exhibits various parts arranged in a particular manner. There are three forms of these, characterizing the different classes of plants. Some are named Exogens (growing from without), in which the stem consists of a central part, of a soft and spongy texture, named the pith, surrounded by one or more layers of wood, enclosed in a ring of bark. This structure is seen in a twig of hazel or willow, and in the woody rings, each of which marks the annual growth of the tree, in the oak or pine when cut down. The Endogens (growing from within) have no pith or annual rings, but the woody fibres mixed up with the soft tissue quite irregularly, though sometimes, as in the palm, more numerous on the outside; they also have no proper bark. The Acrogens (growing from the point) are usually classed with the latter, but are distinct, the stem being formed of hard plates folded on each other, and doubling about among spongy matter. They never increase in thickness, and grow only at the points. Of this the stalk of the fern is an example.

The leaves of plants exhibit many peculiarities of form, which are useful in distinguishing one species from another. These forms are thought to depend considerably on the manner in which the veins or ribs, often well seen in a partially decayed leaf, are arranged. In some, as the ferns, these veins are forked,

always dividing into two branches which do not interlace with each other. In Endogens the veins run parallel to each other without branching, and are joined by small veinlets at right angles to the former, as seen in a blade of grass. In our common trees, on the other hand, the veins divide into numerous ramifications, which unite together into a complicated network. Here therefore, as in the stems, we find three divisions of plants with distinct structure. The uses of the leaves is thought to resemble that of the lungs in animals, the sap transmitted to them from the roots undergoing a kind of change. This is sometimes compared to the process of digestion in animals, the sap or food being thus prepared for assimilation with the substance of the plant. The principal changes seem to be, that much of the water absorbed by the roots is evaporated, and the carbonic acid contained in it, or inhaled from the atmosphere, is decomposed, the carbon being retained in the plant, whilst the oxygen is given back to the air. Not only the leaves, but all other green parts of the plant, aid in this process, to which light seems to be essential. Hence plants only thrive in the light; and where this is excluded they speedily die, or become pale, blanched, and unhealthy. During the night, plants seem even to absorb oxygen and part with carbonic acid, but the reverse is the general process; and plants thus tend to purify the air contaminated by combustion and the respiration of men and other animals. The importance of light to vegetation is shown not only by artificial experiments, but in nature, where plants exposed to its influence are much healthier, of a deeper green colour, and possess a superior flavour and more odoriferous smell. Hence also the most aromatic herbs and the finest fruits are found in warm countries. This is also the reason why wood from trees which have grown fully exposed to the light, is tougher and more durable than that from thick forests where it is excluded. In like manner, the want of sufficient light to enable them to digest the sap properly, renders potatoes grown in the shade watery and less nutritive.

Besides carbon, some other solid matters are deposited in the tissue of plants. Thus, silex is found in the stalks of grass, our common grain, in the bamboo, in teak, and other kinds of hard woods. Lime is also common, together with magnesia, soda, potash, sulphur, and several of the metals. It has been calculated that copper forms eight parts in a million of coffee, and four and a half in a million of wheat; whence it results that about 1200 lbs. of this metal are every year imported into Europe with our coffee, and that the French consume about 8000 lbs. annually in their bread.

The most beautiful and curious part of most plants is the

flower. This consists of several organs, of which the external and most conspicuous have been already enumerated. The lowest part is the calyx, which serves as a support to all the rest of the flower. It is usually green, and assumes a great variety of forms, but in some flowers is altogether wanting. Within this is the corolla, the bright-coloured part of the flower, and either whole, forming a tube, or divided into various pieces. Within these is a circle of organs, named stamens (Fig. 83), consisting of a threadlike stalk or filament (*a*) supporting a small bag or anther (*b*), full of a fine dust or pollen. This is the most general form of the filament and anther, but others are not uncommon, as in the heart's-ease (*i*, in Fig. 82), where they are thin, flat, and of a pale yellow colour. The number of stamens, when small, as from one to ten, is usually pretty constant in the same species, and often corresponds with the number of divisions in the calyx and corolla, but when very large is far more indefinite. Within these, and in the centre of the flower, is the pistil (*k*) (Fig. 82), which consists of the ovary (*a*) (Fig. 84), the style, or stalk (*b*), and the stigma (*c*). The ovary continues to increase in size after the rest of the flower has withered, forming the fruit, and containing seeds. The number of pistils and of divisions in the ovary, as well as of the seeds it contains, is very various. The matured ovary or fruit also assumes many distinct forms, which are familiar to all, as, for example, in the pod of the pea, the fleshy part of an apple or orange, and the hard shell of a nut.

Fig. 83.

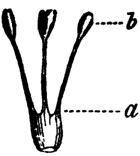
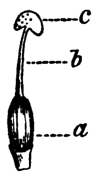


Fig. 84.



The seeds of plants serve for the multiplication of the species, being dispersed over the earth in various ways. Some plants, like the common broom, scatter their seeds when ripe by the bursting of the pod; others, like the thistle, are attached to a light down, which enables the wind to waft them to a distance; while others are provided with hooks, by which they adhere to the fur of beasts or the feathers of birds, and are thus transported to situations fit for their growth. In these, and many other ways, plants are dispersed from one region to another, man being not the least active agent in propagating the more useful varieties. The immense number of seeds also prevents the destruction of the species, notwithstanding the amount consumed by animals. Thus a single head of the white poppy is said to contain 8000 seeds, a plant of tobacco to produce 360,000,

and a stalk of spleenwort even a million. Plants are also multiplied by buds, grafts, cuttings, and other ways, of which the potato is a singular example, the real seed or apple being almost never used. The banyan-tree of India, sending out shoots from its horizontal branches, which, reaching the ground, take root and form new stalks, till a single tree multiplies almost to a forest, differs from these in several respects (Fig. 85).

Fig. 85.

There are several other less important parts in plants, which need not be noticed, though very curious in structure, and interesting on account of the uses they serve. Their various modes of growth are also well deserving of study, from the time the seed, cast into the earth, begins to germinate, till it has risen up into a beautiful flower or mighty tree. Some plants live only one year, and then dying wholly, leave their now perfect seed to continue the race. Some survive two or three years, and others during many centuries, as the oak in this country, of which that at Elderslie, near Paisley, named Wallace's Oak, is said to be at least seven hundred years old, whilst some others are thought to be even twice this age. The yews at Fountain's Abbey, in Yorkshire, are probably twelve centuries old. Still more ancient are the Baobab trees of Africa, estimated at five thousand years; and a yet higher antiquity has been ascribed to some American trees, though on no very certain grounds. The size is equally various even among trees. Thus three of the famous chestnuts on Mount Etna are respectively 64, 70, and 180 feet in circumference. The dwarf birches of Norway, several of which may be preserved between the leaves of a small

pocket-book, furnish a striking contrast to the lofty pines which grow in other parts of that country.

The distribution of plants on the earth depends partly on soil, and partly, but in a higher degree, on climate. Hence the surface of the earth is divided into various botanical regions, each inhabited by its peculiar group of plants. In the warm and moist countries between the tropics, vegetation attains its highest state of luxuriance, and far exceeds, both in variety of species, and in beauty of flowers and foliage, any thing seen in colder climes. Many of its most remarkable tribes, as the palms, disappear in the temperate zone, where others, as the vine and our various kinds of grain, abound. Towards the polar circle a group of still hardier plants succeed, till in the far north mosses and lichens almost alone remain. Even in the same country, and within a few miles, a similar gradation may be seen in ascending lofty hills, like Etna or the Alps.

The number of distinct species of plants growing on the earth probably exceeds a hundred thousand, and some botanists think even double this number. To give a full description of each separately would require enormous labour, and when completed would serve little purpose, as no memory could retain either the names or characters. Hence it is necessary to classify plants according to their relations and the various properties in which they correspond. Those which agree in all their permanent characters, and resemble each other more than any thing else, form a species; a genus comprises many similar species; and families many similar genera. Linnæus, the founder of scientific botany, classed all the flowering-plants from the number and relations of their stamens and pistils, and thus produced an artificial system of great utility for readily discovering the name of any species. But this method separated plants that closely resembled each other in appearance and properties, and botanists now prefer what is called the Natural System, in which the various species are arranged in families according to the resemblance in all their parts, so that those most closely related are brought immediately together. In this way the whole vegetable world is divided into orders or families, of which Dr Lindley makes 295. He also finds that the flowering-plants of Britain belong to 104 of these, but ten-elevenths of the whole are comprised in thirty-five families. To understand the principles on which these divisions are formed would require far more acquaintance with the structure of plants than the reader can be supposed to possess, and we shall therefore merely notice a few of those families that contain well-known and interesting species.

The lowest classes of plants are those without flowers, of which the mushroom-tribe or fungi are very numerous. They

grow especially in damp woods and fields, sometimes on the ground, sometimes on other plants. A few, as the common mushroom, are eatable, but the greater number have poisonous properties. The mould on bread and the rust in wheat belong to this class of plants, as may be seen when they are examined by the microscope (Fig. 86). The lichens are those powdery,

Fig. 86.

Bread Mould. Fruit Mould.

membranous, or leafy substances found covering trees and stones. They are the first plants that take root on barren rocks, and form a soil for higher species. Some, as the Iceland moss, are articles of food, and many, as the archil, are valuable dyes. The mosses, natives especially of the temperate and frigid zones, have more resemblance to perfect plants than the former, but are inferior in this respect to the ferns, with beautiful feathery leaves, and in warm climates often a stem twenty feet or more in height, when they bear some resemblance to the palms.

Plants with flowers are usually divided into two classes, corresponding with that distinction in the structure of the stem formerly mentioned. The first of these, the Endogens, also named Monocotyledons, from the seed consisting of only one lobe or cotyledon, as in wheat or barley, have stems increasing from within, leaves with parallel veins, and flowers, the parts of which are usually three, or some multiple of this number. To this class belongs the Gramineæ or grasses, which are very numerous, and of the utmost importance to man. Not only the pasture that feeds our flocks and herds, but our common species of grain—wheat, oats, barley, and rye, and in warmer lands, millet, rice, and maize or Indian corn—all form part of this family. The oats and barley grow farthest north, and in Europe are cultivated even within the polar circle. Next to them is the rye, more common in the northern parts of continental Europe, where it furnishes a greater part of the bread of the people than in our country; though probably a native of India or Persia, it does not succeed in southern countries, except in mountain-districts. Wheat requires a still higher temperature, and consequently is found farther south, where also the millet is much cultivated. All these were unknown in the western continent before its discovery by Europeans, but it possessed

the maize, now common in the southern part of Europe. Rice, requiring much heat and moisture, is the true grain of the torrid zone, and is cultivated in the south of Asia and the United States of America. The sugar-cane is also a species; and the bamboo, from fifty to sixty feet high, is only a gigantic grass. The palms, lofty trees with a branchless stem and single bunch of leaves at the top, likewise fall under this class. Many of them furnish valuable food, as the date and cocoa-nut trees; and their leaves and wood are converted to many useful purposes. The greater number of them are natives of the warmer regions of the earth, and three of the most important are represented in Fig. 87. The Lilies, comprising the tulips and similar flowers,

Fig. 87.

Date, Cabbage, and Cocoa-nut Trees.

the aloe, asparagus, onion, and leek, are another family. Some of our spices are furnished by plants of this class, as ginger and cardamom seeds; the bananas, plantain, and the ananas or pine-apple, also belong to it, but are mostly confined to tropical countries. This is also the case with the dragon-tree, somewhat similar to the palms, found in the East Indies and Canary Islands, where that represented in Fig. 88 is forty-eight feet in circumference and sixty feet high.

Fig. 88.

Dragon-tree of Orotava.

The second division of the flowering-plants is the Exogens, which, as already noticed, have stems growing by additions from without, and leaves with netted veins; and are named Dicotyledons, from the seed consisting of two lobes, as may be well observed in the pea or bean. The parts of their flowers are usually four or five, or multiples of these numbers, as eight or ten. The finest and most valuable trees and many highly useful plants belong to this class. The Laurels, of which the common evergreen-bay is an example, furnish, in the warm regions of the East, the cinnamon-tree, whose bark is the well known spice; the cassia; the camphor-tree, the substance used being a gum that exudes from its bark; and the nutmeg-tree, producing not only the nuts, but also mace, which covers the outside of the nutmeg, and has a similar flavour. The Solaneæ are a curious family, containing not only the henbane, deadly nightshade, and other poisonous plants, but also the tobacco plant and the potato, both introduced into Europe from the western continent. The former is now extensively cultivated in Southern Europe; but the best is still grown in America, and upwards of twenty-two million pounds weight are every year imported into this country. The blossoms of the latter furnish a good illustration of those peculiar to this family, most of the species of which possess more or less poisonous properties, even

the potato, when uncooked, having a stimulating effect similar to the nightshade, but much milder. The Jasmine family, named from that beautiful dark-green odoriferous shrub, usually also includes the Olive tribe; of which that tree, common on the shores of the Mediterranean, and valued for its fruit and oil, the ash, the flowering species of which produces manna, the lilac, and privet, form a part. The Labiatæ, with irregular flowers, gaping like the mouth of an animal, contain many aromatic and tonic plants, as thyme, lavender, mint, rosemary, and sage. The Heaths (Ericaceæ) form one of the most beautiful families of plants, comprising the azalea, rhododendron, and kalmia, together with that large genus whence it is named. This contains from 300 to 400 species, all confined to the old world, the most beautiful being brought from the Cape of Good Hope, and cultivated in greenhouses. Vaccineæ, formerly joined to this family, contain many species with eatable fruit, as the crowberry and cranberry, whereas the former are often poisonous. The Composite Flowers, like the thistle and daisy, are a very numerous family, comprising about a tenth of the whole vegetable kingdom. What is usually named the flower in these plants is in reality many small flowers or flowerets collected together into one head. Lettuce and artichokes are used for food, chamomile and wormwood for medicine; and many, as dahlias, marigolds, asters, and others, are cultivated as ornamental plants. The Rubiaceæ are named from the red dye furnished by some of the species, as the madder; while others are valuable medicines, as the ipecacuanha, and the cinchona or Peruvian bark-tree, both natives of South America. The coffee-tree, which grows in moist and shady situations in hot countries, has been transplanted from Arabia to both the Indies. Coffee was first introduced into Venice in 1615, in 1652 into England, and six years later into France. The quantity exported from the different countries where it is grown is estimated at 270 million pounds, of which this country consumes about a tenth part, France a fifth, and the United States of America above a third.

The Umbelliferous Plants are a large and well marked natural family, distinguished by their flowers growing on numerous branching stalks, forming a flat or slightly-rounded head or umbel, as it is termed. The plants it contains are mostly aromatic, but many highly poisonous, as the hemlock tribe, and common celery when unblanched. Others are used as food; for example, the carrot, parsnip, parsley, caraway, and coriander; whilst the roots of many, though deadly poison when raw, are said to become innocent when cooked. The geraniums are beautiful plants, valued as ornaments of the garden; and the

lint, formerly united with them, is of great importance for the flax formed from the fibres of the stems. The camelias, natives of China and Japan, are beautiful greenhouse plants, and closely allied to the tea-plant, also a native of the same countries. Tea was only introduced into Europe in 1666, but is now in great request, especially in Britain and Russia, the former, in 1842, using above thirty-six million pounds weight. The vine is probably a native of the east, but grows only in the central part of the temperate zone, succeeding best in Southern Europe, on the shores of the Mediterranean. Soil and climate give rise to many varieties of the vine, producing different kinds of wine. Of this it is calculated that 1500 million gallons, worth at a moderate computation 330 million pounds sterling, are annually produced, and all, except about a twelfth part, in Europe. The family of the Poppies is well known, the thickened juice of one of them being the drug opium, principally manufactured in Turkey and India. The Cruciferæ, named from the crosslike arrangement of their four petals, contain many plants useful to man, as the cabbage, cauliflower, and turnip. The Ribes include our common gooseberries and currants, along with several fine flowering shrubs. The Rosaceæ are a highly interesting family, containing not only the flower whence they are named, but also some of our finest fruit-trees. The apple is supposed to have come from the east; the pear is said to have been introduced into Britain by the Romans; and the cherry, plum, peach, apricot, and nectarine, though also natives of warmer climes, are now naturalized in the temperate parts of Europe. Even the strawberry, rasp, and bramble, belong to this very valuable family. Another important family is the Papilionaceous plants, named from the resemblance their expanded flowers bear to a butterfly. The pea and bean are good examples of this class, and probably natives of Southern Europe. The laburnum, the cassia, whose leaves form senna, the acacia, indigo, logwood, and tamarind-tree, have similar flowers, and the different varieties of clover are included in the same order. The Urticeæ, or nettle-tribe, contains many species very distinct in appearance, as the plant whence it is named, the hemp-plant, the hop, the elm-tree, the mulberry, fig, and bread-fruit tree, but all united by the similarity of their flowers.

The Willows and Poplars form a large and well-known family, with many useful properties. The Alder and Birch are united in another, the latter being one of the hardiest trees known, some of the species being the last to yield to the cold of the frigid zone. The Oak is dispersed over most parts of the earth in numerous species. Some English oaks have measured from twenty to forty feet in circumference, and the strength and

durability of the wood is superior to that of any other tree. The cork is the bark of a species of oak common in Southern Europe, especially in Spain; and the fruit of another, growing in Greece and Asia Minor, is eaten. The last family we shall mention is the Coniferæ, or cone-bearing plants, of which the pine and fir, in many species and varieties, form good examples. They are almost all evergreens, with narrow pointed leaves. Besides the trees named, it includes the yew, the cypress, the cedar, larch, juniper, lignum vitæ, and many others. The few families mentioned show the richness of the vegetable kingdom in species useful to man, and also the manner in which they are combined by botanists into natural families. Capricious as at first sight many of these unions may appear, it will be found that the plants contained in them have many important points of resemblance, so that a knowledge of one gives much information concerning the properties of the others.

SECTION VII.—ZOOLOGY.

THE name of this science, like the others, is derived from the Greek, and means an account or discourse of living beings. It describes and classifies the different tribes of animals found on the earth, and points out their varied habits, properties, and uses. The immense multitude of species of animals renders such a science both useful and necessary, naturalists having now enumerated at least a hundred thousand distinct kinds, whilst it is conceived that upwards of half a million inhabit the earth. It is not easy to point out the characters which distinguish the lower classes of animals from certain plants; but the possession of a stomach or receptacle for food, of irritability and nervous sensation, and of the power of motion at least in limited spaces, seem peculiar to them. The higher classes have a muscular structure or flesh, covering a skeleton or framework of bone, and thus composing the organs by which their motions are performed. A brain or centre of nervous action, a heart for circulation of the blood, and lungs by which its purity may be restored by communication with the external air, are also found in these classes of animals. Most of them have some external covering, as hair, feathers, scales, by which they are protected from the weather; and many also possess weapons of defence, as horns, claws, teeth, or stings, to preserve them from the attacks of their enemies. Various classifications of animals have been proposed, but that of Cuvier, which is most generally adopted, is as follows:—*First*, Vertebrated Animals, or those having a back-bone or spine, which,

with its termination, the skull, encloses and protects the brain and spinal marrow, the central organs of the nervous system. *Second*, Molluscous Animals, or those of a soft texture and no skeleton. *Third*, Articulated Animals, whose body consists of a number of articulated joints or rings; and, *Fourth*, Radiated Animals, in which the organs are disposed like rays proceeding from a centre. A fuller account will be given under each class of its distinguishing characteristics.

The first division of Vertebrated Animals, having a firm and jointed skeleton, attain a larger size, and possess greater powers of motion than the other classes. They have also a larger and more perfect nervous system, and show more intelligence. Their structure approaches near to that of man, who, could we consider him merely as an animal, would be placed in this division. The first class is the Mammalia, or those which produce their young alive, and for a time suckle them. It is the most important of all to man, though containing the fewest kinds. Cuvier made man himself the first order of this class, or the two-handed; but in this point we would depart from his arrangement. His second order is the Quadrumana, or four-handed animals (Fig. 89), including the various tribes of apes, monkeys, and baboons.

Fig. 89.

Formed principally to live in forests, these animals have their feet or hands adapted to climbing, and they walk on the ground or stand upright with difficulty. The form of their head differs much from that of man, their forehead being low, the nose flat, and the mouth projecting. Many of them exhibit the most sa-

vage dispositions and disgusting habits; but others, especially the smaller varieties, are very gentle and playful. The Orang-outang, from three to six feet high, is the largest, most intelligent, and docile, but cannot in any respect be compared even with the most degraded tribes of savages. In its natural state it walks on all-fours, and only supports itself erect with difficulty.

The third order of Carnaria, or Flesh-eaters, comprehends the Cheiroptera (wing-handed), so named from the wings formed by the membrane which joins the long fingers of their hands. The Bats, of which there are very numerous species, belong to this order, and are found both in the temperate and torrid zones, the largest varieties being in the latter. Some, particularly in warm climates, live on fruit, and others, as our common bat, on insects, which they seek by night. The Vampire has been known to suck the blood of men when asleep, though the accounts of it are much exaggerated. The next family of Insectivora feed on insects, and are chiefly nocturnal animals, like the Hedgehog, which becomes torpid during the winter; or live below ground like the Mole and Shrew. The mole burrows with great facility, its strong snout, its broad paws armed with nails, and the whole structure of its body, being evidently designed for this subterraneous mode of life. In adaptation to this also, its eyes are so small and deeply sunk in its head, that some naturalists have doubted of their existence; but its senses of hearing and smell are very acute, enabling it to discover the worms and grubs on which it subsists. The third family, the Carnivora, live more exclusively on flesh, and possess in a higher degree that strength and sanguinary disposition which are thus rendered necessary. Their large pointed canine or eye-teeth are adapted for holding and tearing their prey, whilst the sharp and rugged surface of their grinders, with the powerful muscles of their jaws, which only move directly up and down, are well fitted for masticating their food. These characters are less strongly developed in the first section of Plantigrades, so named from walking on the soles of their feet. The Bears are the largest and most ferocious of this division, but can subsist entirely on vegetable food. The White or Greenland Bear, clothed in long shaggy fur, and living among the floating icebergs of the arctic seas, where it feeds on seals and fish, is the largest species (Fig 90). The Brown Bear is still common in Scandinavia and the Alps, but is inferior in strength and fierceness to the Grizzly Bear of the Rocky Mountains, which has been known to carry off the carcass of a buffalo weighing a thousand pounds. The Badger, living on roots of plants and on small animals, is not uncommon in Britain, concealing itself in holes formed amidst woods and rocks. The

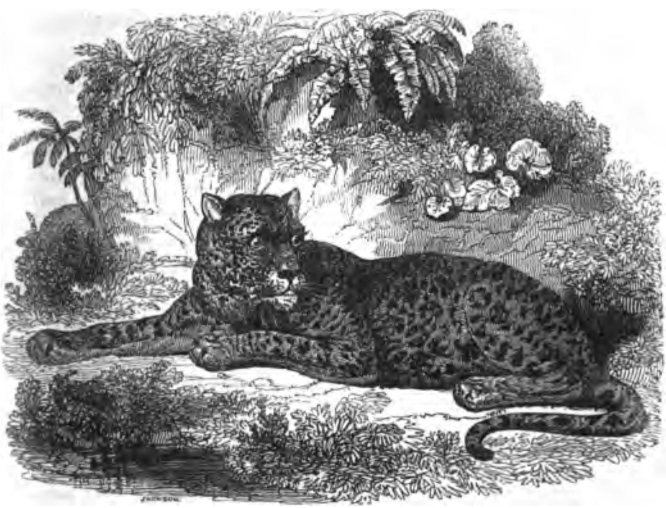
Fig. 90.

Raccoons of America and the wide-spread Gluttons also belong to this section.

The Digitigrade animals, or those that walk on their toes, are another section of Carnivora. One group includes the Polecats; the Weasel, a bold active animal, of a reddish brown colour, with a long slender body, destroying not only mice, rats, and small birds, but even poultry, game, and hares; the Ferret, chiefly used for catching rabbits and vermin; the Ermine, changing from brown to white in winter; the Sable, a single skin of which sells for ten or twelve pounds; and, in our own country, the Otter, frequenting holes in the banks of rivers, and feeding on fish. Another group comprises the Canine Animals, of which man's faithful companion, the Dog, whose numerous varieties are all thought to have descended from one original stock, resembling the shepherd's dog, is a good example. The Wolf, of a grayish yellow colour, about two and a half feet high, and of a ferocious cowardly disposition, is closely related to the last. It is still found in the more unfrequented parts of the Continent, was very common in Scotland so late as the end of the sixteenth century, and in Ireland only extirpated in the beginning of the eighteenth. The Jackals inhabit the warmer parts of Asia and Africa, hunt in packs, and feed both on living and dead animals. It is commonly named the lion's provider, but the connexion between the two animals is merely accidental. The Fox, celebrated for his cunning and sagacity, still maintains his place among our quadrupeds, though very destructive to game, poultry, and young lambs. In the northern countries some species become white in winter. The Hyena, of which there are several kinds, has a

fierce ungainly aspect, lives in the warmer parts of the earth, and feeds chiefly on dead carcasses, which it drags into the caves it inhabits. It is somewhat related to the next group of feline animals, of which our domestic Cat is a most characteristic example. They are distinguished for ferocity, strength, and agility, even the cat never losing these peculiarities of the savage state, but when provoked quickly showing its mischievous disposition, and, unlike the dog, in general more attached to the place it inhabits than to mankind. The Tiger closely resembles it in all points except size. It is found in most parts of Asia, and is remarkable for fierceness, strength, and cunning. When full grown it is about three feet high, six long, and of a yellowish colour, marked with black bars. The American Tiger or Jaguar is a less formidable animal

Fig. 91.



(Fig. 91). The Lion is about the same size, but his large head and long mane give him a more majestic aspect. The stories of his courage and magnanimity are however unfounded, and the king of beasts is no less cruel, unsparing, and cunning than his congeners. The Leopard, Panther, Lynx, and the Wild-cat, which is larger and stronger than the domestic one, also belong to this group.

The Amphibious Carnivora live either on land or in the

water, below which they can remain a long time, though they must come to the surface to breathe. They feed on fish, and live amidst rocks, where they are often seen basking in the sun. The largest is the Walrus, Morse or Seacow (Fig. 93), found in the arctic regions, and captured for its skin, tusks, and oil. Species of the Seal group are common on our shores, but they are more abundant in both the north and south polar oceans, where they furnish the natives with materials for food, clothing, fuel, houses, and boats.

The next order is the Marsupial, or Pouched Animals, remarkable for a pouch in the belly, where the female carries her young, which when born are very small and imperfectly formed. The Kangaroo of New Holland belongs to this class. It sits on its hind legs, when it is nearly as tall as a man, and, making little use of its fore feet, rather leaps than runs. The Opossum, a native of the warmer parts of America, is somewhat similar in form.

The order of Rodentia, or Gnawers, is more numerous and widely spread. They are named from the manner in which they file or gnaw their food with their front teeth, which, growing very fast, and being hardest on the outer side, have a wedge-like shape and a sharp edge. The Beaver, remarkable for the skill with which it constructs its houses and dams, and much valued for its skin, belongs to this order. It is about two feet long, and its broad tail is covered with scales. The Hare and Rabbit are also included in it, with the numerous varieties of Squirrels. These live principally in trees, have a large bushy tail, and the Flying Squirrel also an expansion of the skin from the fore to the hind legs, which acts as a parachute. The Lemmings in Norway, with the various kinds of Rats and Mice, are also rodents.

The Edentata, or toothless order, have no front teeth, but in other respects exhibit little resemblance or connexion. The Sloths, formed to live in trees, on whose foliage they feed, display considerable agility in their own proper sphere, but are very helpless on the ground, and hence their reproachful name. The Armadillos, covered with a hard shell, divided into compartments like little paving stones, and the Pangolins or Scaly Ant-eaters, defended by sharp scales arranged like tiles, feed chiefly on insects. The Ornithorhyncus, or Duck-bill of New Holland, presents a still more curious form. its muzzle being compressed and closely resembling the bill of a duck, its feet webbed, and its young, it is said, produced from eggs. In other respects it belongs to the mammalia, and frequents the banks of rivers.

The Pachydermata, or thick-skinned order, includes some of

the largest terrestrial animals. The Elephant, of which there are two species, one in India, the other in Africa, is remarkable for its great size, being often ten or twelve feet high; its trunk composed of many thousand muscles, which serves it for a hand; and also for its intelligence, which, however, does not seem superior to that of the dog. The Asiatic species is still tamed, and used as a beast of burden or for war. The Rhinoceros is similar, but smaller, and with no proboscis. The Indian species has deep folds in its skin, and one horn on its nose; the African has no folds, but two horns, one behind the other. These horns consist not of bone, but of a fibrous horny substance resembling agglutinated hairs. The Hippopotamus, which inhabits the African rivers and feeds on vegetables, also belongs to this class. More familiar are the Hog and Wild Boar, still found in some parts of the Continent, and the Tapirs of America and the Asiatic islands. The Solidungula, with a single undivided hoof, comprehends the Horse; the Ass, a native of central Asia, where it is still found wild; the beautifully striped Zebra from Southern Africa, and other species.

The next order is the Ruminantia, so named from ruminating or chewing the cud. This depends on the peculiar structure of their stomachs, of which they have always four. The food, slightly chewed, is collected in the first or paunch, whence it passes into the second or honey-comb stomach, where it is moistened and compressed into little pellets, which successively ascend to the mouth, and are again chewed. It then redescends into the third stomach, or *many-plies*, and from that into the fourth, or *read*, where it is fully digested. They live entirely on vegetables, and their grinding teeth are flatter on the top than in carnivorous animals, and not pointed, but divided by ridges or furrows. To this order belongs the Camel, which, formed for traversing the dry and sandy deserts of the East, has a broad flat foot, a reservoir of water connected with the stomach, and the power of closing its nostrils during the sand-winds. The two humps on its back distinguish it from the Dromedary, which has only one, and is of a smaller size. The Lama of Peru, also used as a beast of burden, is an allied species, but much smaller, and has no hump. The Giraffe or Camelopard, a native of Africa, has a spotted skin, and its forelegs and neck so prolonged, that though not larger in the body than a horse, its head yet reaches eighteen feet from the ground, enabling it to procure the leaves on which it feeds. The Deer, with variously branched horns of solid bone, forms many species, as the Roe, Stag, Fallowdeer, Reindeer, Elk, and Moose. The Antelopes have hollow horns, and include the Gazelle, the Gnu, with a body resembling that of a horse, and many other species.

There are numerous varieties of the Goat and the Sheep, of which the latter are all supposed to be descended from the Moufflons, or wild sheep still found in the mountains of Asia and Greece. The Rocky Mountains in America are also inhabited by wild species of these animals (Fig. 92). Of equal

Fig 92.

importance to man is the Ox or Cow genus, including not only the domestic breeds, but also the Urus, Bison, Buffalo, and Musk Ox.

The last order of the Mammalia is the Cetacea, or Animals of the Whale tribe (Fig. 93). These are popularly considered as

fishes, but differ in many important respects. Externally they have the tail-fin horizontal instead of vertical; they have warm blood;

Fig. 93.

Walrus. Narwhal. Greenland Whale.

breathe by lungs; bring forth their young alive, and suckle them. Some feed on herbs, as the Manatus, in the warm parts of the Atlantic; the Halicore or Dugong of the Indian Ocean; and the Stellerus of the arctic regions. Others are carnivorous, as the Greenland Whale, often sixty feet long, and the Rorqual,

upwards of a hundred feet long. The former is much sought after for its oil and the whalebone found in its mouth, where it forms a kind of strainer for its food, consisting of small fish and other marine animals. The Spermaceti Whale of the southern ocean furnishes a finer oil, and also spermaceti, found in cavities about the head. The Narwhal or Sea-Unicorn, remarkable for its long pointed tusks, of which only one generally remains, with the Grampus, Porpoises, and Dolphins, all belong to this order. These generally inhabit the salt water, but some also frequent large rivers.

Fig. 94.

Perils attending the Whale Fishery.

The second class of Vertebrated Animals are the Birds, which produce their young from eggs, are covered with feathers, and organized for flight. To this their whole structure is admirably adapted, their bones being light, but strong and often hollow and communicating with the external air, which circulates far more freely and extensively in their bodies than in any other class of animals. Their respiration and nervous energy also surpass that of all other classes. Their feathers combine great strength and elasticity with lightness, and are preserved from the effects of the weather by the application of an oil which most birds possess in two bags near the tail. The flight of som birds is very

rapid, a hawk being able to traverse a hundred miles in an hour, the eider-duck ninety, and the common crow twenty-five; whilst those that migrate take advantage of the wind, which adds much to their speed. Connected with the stomach is the gizzard, composed of powerful muscles, by which the food is ground down, most birds increasing its power by swallowing small stones. Cuvier divides them, principally from the form of the bill and feet, into six orders, which we shall now notice.

The first order is the Raptores, or Birds of Prey, with strong hooked beaks, and feet armed with sharp and powerful talons. Their eyes are large and piercing, their flight generally very rapid, to enable them to seize their prey; and the female, having chiefly to provide for the young, is usually larger than the male. The first family is that of the Vultures, cowardly birds, with a long beak, weak talons, feeding mostly on carrion, and of dirty disgusting habits. The largest is the Gryphus or Condor, of a blackish brown colour, and measuring twelve feet from tip to tip of the expanded wings. The Bearded Vulture, distinguished by its feathered neck, is the largest European bird, being ten feet across the wings. The Falcons are very numerous, and have the head and neck covered with feathers; their bill and talons are stronger than in the vultures, and they feed mostly on living animals. The True Falcons, or noble birds of prey, as the Peregrine-falcon and Goshawk, both found in Scotland, and formerly trained to hunt, are more courageous; though smaller than the Eagles, remarkable for their size, strength, and longevity. The Golden Eagle, three and a half feet long, and eight from tip to tip of the wings, is of a deep-brown colour, with a black tail, and inhabits the mountains of Europe. The Kite or Glead, including the Buzzards and the small Sparrowhawk, are well known. The Owls, or nocturnal birds of prey, have a large head, great conspicuous eyes, and silky feathers, enabling them to glide softly through the air, and surprise the mice, insects, and small birds on which they prey. The most remarkable are the Horned Owl, with two tufts of feathers on its head, the Barn Owl, the Brown Owl, and the great Snowy Owl of the north.

The second order, that of the Passerinæ, or Sparrow-like Birds, is the most numerous of the whole. They vary much in their power of flight and habits, living on insects, fruit, or grain, and some of the first family even on other birds. This is the Dentirostres, with a notch or tooth on their bill, of which the Shrike or Butcher-bird, the Thrushes, the Warblers, including the Nightingale, the Wrens, and Wagtails, are examples. The Fissirostres have a short broad beak, opening very wide, enabling them to swallow the insects they capture while on the wing. They consist of the various Swifts, Swallows, and Goat-

suckers, of which the Whip-Poor-Will of America is a species. The Conirostres have a strong conical bill, and live principally on grain. To them belong the Larks, which build their nests on the ground; the Titmice, which inhabit holes in trees, where they lay up a store of seeds; the Buntings, Sparrows, including the Finches and Linnets, of which the Canary, in its native state of a green colour, is a variety; the Crows, remarkable for their cunning and the acuteness of their smell, including the Raven, Rook, and Jackdaw; the Magpie, Jay, and, last of all, the Birds of Paradise, with long silky feathers, having a metallic lustre. The last inhabit New Guinea and the surrounding islands, where they feed on fruits, especially aromatic herbs. The Tenuirostres have a long slender bill, and include the Humming-Birds, the smallest of the winged tribes, with brilliant plumage, almost equalling the precious stones in lustre; the Kingfishers; and the Hornbill, with curiously enlarged beak.

The third order, the Scansoriæ, or Climbers, have two toes directed backwards, the better to support their weight, and live on fruits or insects. The Woodpeckers are true representatives of this order, to which the migratory Cuckoo, celebrated for its want of parental affection; the Toucans, with an enormously large beak; and the Parrots, with hooked bills and beautiful plumage of the brightest colours, also belong. The Parrots feed on fruits, are found in the warmer parts of both hemispheres, have a thick fleshy tongue, and more muscles in the throat and mouth than any other bird, which gives them a facility of imitating the human voice.

The fourth order, the Gallinaceæ, named from their affinity to our domestic fowls, are of great importance to man. It includes the Peacock, a native of Northern India; the Turkey, originally brought from America, where it is still found wild in the woods; and the Pheasant, from Western Asia. Some naturalists derive our Common or Domestic Fowl, now dispersed almost over the whole world in numerous varieties, from Sumatra or Java, but this is uncertain. The Blackcock, Grouse, Ptarmigan, Partridge, and Quails, also belong to this order; and the various tribes of Pigeons, of which the Rockdove is thought the progenitor. When domesticated they increase with great rapidity, so that a single pair would in four years produce upwards of fourteen thousand. Some flocks of the Passenger Pigeon in America have been estimated at upwards of 2230 millions.

The fifth order, the Grallatores, or Waders, are adapted to their mode of life by long naked legs, to which the length of their neck and bill corresponds. They generally frequent marshes, feed on fish, reptiles, and insects, have long wings, and fly well. The first family, including the largest of known birds,

the Ostriches and Cassowary, forms an exception to the general character of the class, the former living in the sandy deserts of the old world, and both feeding on fruits or grain, and unable to fly. The Ostrich is from six to eight feet high, and runs with exceeding swiftness. The remains of a more gigantic genus, named the Dinornis, estimated at ten feet high, have been found in New Zealand. The Dodo, also a large bird, formerly living in the Mauritius, is now supposed to be extinct. The Plovers, Lapwings, Cranes, Herons, and Storks, with the Spoonbill, named from the form of its bill, have more of the character of the order. The White Ibis, reverenced by the ancient Egyptians, with the scarlet-coloured species found in America, the Snipe, Woodcock, Curlew, and Sandpipers, natives of our own land, have a longer and more slender bill. The Rail or Corncraik, of a fawn-brown colour, mottled with black; the Coot or Waterhen, with black plumage; and the Red Flamingo, remarkable for the length of its neck and legs, form a family characterized by their long toes, fitted for walking in the marshes they frequent.

The sixth order, the Palmipedes, or Web-footed Birds, are still more aquatic in their habits. Their feet are placed far back, and more adapted for swimming than walking, and their thick oily plumage is well fitted to preserve them from the effects of the water. One family includes the Divers, Grebes, Auks, and Penguins; another, the Petrels or Mother Carey's Chickens, the Albatross, Gulls, and Terns—all of which frequent the sea, and swim under the water, using their wings like fins. The Pelican, with a large bag below its mouth; the Cormorant, of a dingy green colour, and sometimes trained to catch fish for its master; and the Solan-goose, so abundant on the Bass Rock and some of the Western Islands of Scotland, form a third. The Ducks comprehend the Swan, of which a black species has been found in New Holland, the Goose, and the Duck properly so called. Of these very many distinct species are known, as the Mallard, the stock of our common Tame Duck; the Wild-duck, found in most northern countries; the Eider-duck, valued for its flesh and eggs, but especially for its fine down; and the Sheldrake, or Muscovy-duck, originally from South America, where it perches on trees. This is the last family of this class of animals.

The third class of Vertebrated Animals comprises the Reptiles. In them only a part of the blood that reaches the heart passes through the lungs, and is thus brought into contact with the external air. In consequence of this, their blood is cold, their muscular energy small, their motions slow, and their sensibility obtuse. Their brain is also small, and they continue to live and move long after they have been deprived of it, and even of

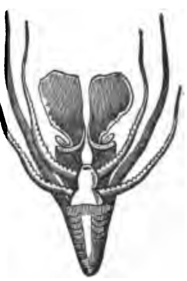
the whole head. The heart beats for hours after its removal, and they then continue to move about as if uninjured. Like the last class, they are oviparous, or produce their young from eggs. They are divided by Cuvier into four orders. The first is the Chelonia, or Tortoises, whose body is covered by a double shield, formed of the expanded ribs and breastbone, their skeleton being thus external. Some live on the land, as the Common Tortoise, some in the fresh water; and others in the sea, as the Hawk's-bill Turtle, producing the best tortoise-shell, and the Green Turtle, so much prized by epicures. The last sometimes weighs eight cwt., and lays a thousand eggs in a year. The second order is the Saurians, or Lizards, with four legs and a scaly covering. The Crocodiles, of which there are several species in the rivers of warm countries, the Lizards, and the changing-coloured Chameleon, are well-known families of this order. The Ophidia, or Serpents, have no feet, and, crawling on the ground, best deserve the name imposed on the class. Many live in water, others on land, and a number principally on trees. Some have a fang, or hollow tooth in the front of the upper jaw, which communicates with a poison-bag above, and thus conveys the venom into the wound they inflict. Of this kind are the Rattlesnake and Adder—the former from America, and very poisonous; the latter common in our own country, where, however, its bite is rarely fatal. The Boa Constrictor, thirty feet long, is not poisonous, but after crushing its victim in its folds, swallows it whole. The fourth order is the Batrachia, or Frog-like Animals, which commencing life as tadpoles, with gills like those of a fish, in their perfect state breathe by means of lungs. The Common and Eatable Frogs, the Treefrogs, which live principally on trees, and the Toads, with the Sirens, Proteus, and Salamanders, belong to this order.

The fourth class of Vertebrata is composed of the Fishes, which live in water, and breathe by gills or bronchiæ, through which the blood circulates, and is thus brought into contact with the oxygen contained in this fluid. Their body is generally formed for passing easily through the water, being as evidently adapted for swimming as that of birds for flight. Their eye is also fitted for the medium they inhabit, the cornea being very flat, with little aqueous humour, whilst the crystalline lens is very hard, and nearly globular. They produce their young from eggs or spawn, and are wonderfully prolific, the roe of a single herring containing from 20,000 to 30,000 eggs, that of the carp 200,000, and that of the flounder upwards of a million. The fishes form two great divisions: those with bones, or true fishes; and those whose skeleton is cartilaginous or gristly. Of the former, the most numerous order is the Acanthopterygii, or Spiny-fins, as

the Stickleback, Perch, and Mackerel. The Mullet, some of the Flying-fishes, and the Swordfish, also belong to it. The Malacopterygii, or soft-finned, contains many valuable species, as the Carp, of which the Gold and Silver Fish are a variety; the Pike; the Salmon family, including the Trouts; and the Herring. Some of these are migratory, as the salmon, which changes its abode periodically from the salt to the fresh water, returning always to the river in which it was spawned. The herring also appears at certain seasons on the coast, in immense numbers, furnishing food and employment to a large population. The Cod, with the Haddock, Whiting, and Ling; the Turbot, Flounder, and other flat fish, form another order of soft-finned fishes. The Eels, including the Conger, and the Gymnotus or Electric Eel, are also a distinct order. The second class of Fishes, or those with a cartilaginous skeleton, comprises the Sturgeons, the Sharks, the Rays, of which the Torpedo is a sub-genus, and the Lampreys.

The second great division of the Animal Kingdom in the system of Cuvier is the Mollusca, or soft animals, having no backbone or skeleton. They are covered by a skin, or mantle as it is named, in which the shells which many of them possess are contained. Their nervous system forms numerous separate masses, named ganglia, one of which, surrounding the throat, is considered the brain. Their senses seem very imperfect, though taste is usually present, and sight and hearing are found in a few. Many of them are used for food, mother-of-pearl is formed of the shells of some, and others produce the real pearl. They form six classes; the first of which, the Cephalopoda, have the feet placed on the head, as in the Cuttlefish, which contains a black fluid from which ink has been made; and the Paper Nautilus or Argonaut (Fig. 95), which uses its shell as a boat, and its two membranous feet for sails. The Clio, with oblong body, though scarcely an inch long, is the chief food of the whale, and belongs to the Pteropoda, with fins instead of feet. Of the Gasteropoda, which move on their belly, the Slugs and Snails, of which one species is used for food on the Continent, give a good idea. Many seashells belong to this class, as the Welk and Limpet. The Acephala, or headless class, contains the Oyster and the Muscle, well known as articles of food; the gigantic Chama, sometimes weighing 300 lbs.; the Pholas, living in holes it has bored in rocks; and the Teredo, so destructive to piles and ships. The

Fig. 95.



Brachiopoda, with arms instead of feet; and the Cirrhopoda, fastening themselves to rocks or wood by cirri or filaments, of which the Barnacle is an example, complete this class of animals.

The third division of Articulated Animals have the body encircled with articulated rings, generally hard, and supplying the place of a skeleton. Their brain is small, but numerous knots, or ganglia as they are called, dispersed through the body, seem to fulfil its functions to the parts around them. No organ of smell has been found, but some at least possess those of sight and hearing. They form five classes, as follows:—First, the Annulata, or Worms, composed of rings, with no feet properly speaking, and red blood, as the Earthworm and the Leech. Second, the Crustacea, with a solid covering and jointed limbs, of which the Lobster, Crabs, Crawfish, and Shrimps, are examples. The Arachnides, or Spiders, including also the poisonous Scorpions and the Cheesemite, form the third class. The fourth is the Insects, of which from 80,000 to 100,000 species have been described, whilst three or four times as many are supposed to exist. They are named from their body, cut as it were into pieces, and have six legs, and one or two pair of wings. They exhibit a very curious and often complicated structure, highly perfect senses, and very interesting instincts and habits, almost resembling reason. Many are of much direct use to man, as the Silkworm and the Bee; and others prove prejudicial to him, as the Locust, Caterpillar, and Moth. Cuvier makes twelve orders, of which the first, the Myriopoda, or Centipedes, with numerous feet, a repulsive aspect, and, in warm countries, often poisonous properties, is now regarded as a separate class. The second, the Thysanoura; the third, the Parasites, living on other animals, as the Lice on men and birds, and the fourth, the Suctoria, as the Flea, are apterous, or without wings. The fifth, the Coleoptera, or Beetles, have four wings (Fig. 96), the upper pair forming a horny case for the under ones. It contains an almost innumerable variety of species, some of them of great beauty, from the metallic splendour of their wing-cases. The Glowworm, a brownish insect, without wings, is the female of one species. The sixth order is the Orthoptera (Fig. 97), with straight wings, as the Locust, a native of both continents, and very destructive to vegetation during its migrations; the Grasshopper,

Fig. 96.

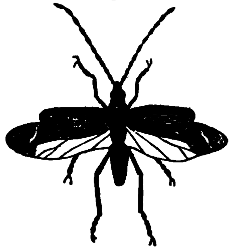
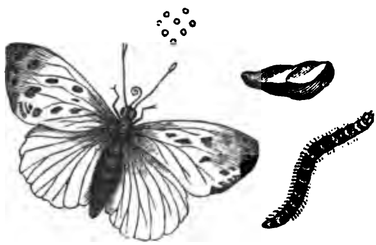


Fig. 97.

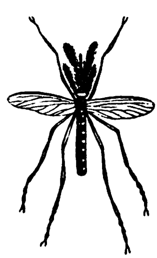
and Cricket. The seventh order is the Hemiptera, or half-winged, among which we find the Bug and the Gall Insects, of which the Cochineal Insect in Mexico is a variety. The eighth order is the Neuroptera, with network wings, as the Dragonfly, a large insect with broad glittering wings, living on prey; and the Ephemera or Dayfly, which lives many years in the water as a grub, but only a few hours in its perfect state. The ninth order is the Hymenoptera, with membranous wings, as the Bee, often found wild in the Russian forests, the Wasp, and the Ant, of which the male and female have wings, the neuters none. The tenth is the Lepidoptera (Fig. 98), with scaly wings, as the Moths and Butterflies, dis-

Fig. 98.



tinguished for their beautiful colours. Their young, or larvæ, are named Caterpillars, one of which is the Silkworm. This is a native of China, but is now dispersed over both Europe and America. The silk is derived from its cocoon, which weighs about 2½ grains, and consists of a thread 900 feet long. The female produces 500 eggs; but the number of these insects may be understood from the fact, that five million pounds of silk are imported into this country every year. The eleventh is the Rhipiptera, with wings folded like a fan; and the twelfth order, the Diptera (Fig. 99), with two wings. To this belongs the Gnat and Mosquito, so troublesome for their bites, with the House and Flesh Fly. These increase with amazing rapidity, one fly producing 20,000 maggots, which in five days come to full maturity. They are of immense importance in ridding the earth of putrid matter, which would otherwise produce disease.

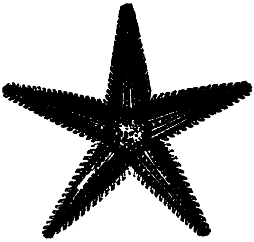
Fig. 99.



The fourth great division of the Animal Kingdom is the Radiata, so named because many of them have their parts arranged as it were in rays round a centre, and sometimes named Zoophytes, or living plants, from the resemblance of some

tribes to the vegetable kingdom. It is a less scientific division than the former ones, and has great need of being remodelled. Cuvier's first class is the Echinodermata, or spiny-skinned, as the Echinus or Sea-hedgehog, and the Asterias or Sea-stars, with five or more rays, often seen on the seashore (Fig. 100).

Fig. 100.



The Entozoa, or Intestinal Animals, as the Tapeworm, live in the interior of other animals. The Acalepha are gelatinous-looking substances, which swim in the ocean, and shine with phosphorescent light at night. The Medusa group, named Sea-nettles, from their stinging properties, somewhat resemble an umbrella in form (Fig. 101).

Fig. 101.

The Sea-anemones belong to the Polypi, and have their name from the flower-like form of the expanded tentacula, and their brilliant colours. The animals producing coral are of the same class; and living and working in community, though individually minute, they rear up whole islands of rock. Sponge is also placed in the same class, though its animal nature has been doubted. The last class is the Infusoria, or Microscopic Animals, so minute that they cannot be discerned by the naked eye. They can only be studied with powerful microscopes, and then exhibit a wonderful variety of forms, and a great complexity of structure. Some increase by division, others by eggs, and in both ways multiply with vast rapidity. Many rocks are formed of their remains, and many marshy pieces of ground consist almost entirely of living animals. Ehrenberg, the celebrated German naturalist, has shown that a great part of the city of Berlin is built on a thick stratum of these animals, many of them still living and moving. The usual accounts of them in books of natural history are very inaccurate, a congeries of many animals being frequently described as only one.

SECTION VIII.—MAN.

THE human race forms the subject of very many distinct branches of science, even the briefest outline of which would fill a volume. Man's physical structure, and the functions of the various organs in their healthy and diseased states, are treated of in Anatomy,

Physiology, Pathology, and the other departments of the medical sciences. His intellectual nature is the subject of Mental Philosophy or Psychology, of Logic, and Metaphysics; his moral nature, and the rule of his life, of Moral Philosophy; his relation to the Deity, of Theology. Man, as existing in society, gives rise to the sciences of legislation, of government or politics; and of political economy, or regulations concerning trade, manufactures, and commerce. These, and other sciences, are closely connected with man, but even those which seem more distinct have yet an intimate relation to him. By his corporeal structure man is connected with the animal kingdom, and is usually regarded as forming a part of it, though, from the very different character of his mental and moral nature, with some impropriety. Even his bodily frame is so far adapted to his higher faculties as to separate him very widely from all the other creatures that inhabit this lower world.

The most striking peculiarity in man's bodily structure is, that he is a biped, or two-footed animal. He walks erect, and supports himself with ease on his feet; whilst his hands, constructed with such wonderful skill, are ever ready to execute all the designs of his mind. The hand, formed by the power of opposing the thumb to the other fingers, is so much more complicated in man, and adapted to so many more intricate offices, that we may regard it as exclusively his own. The hands of the monkey tribe are in truth only a modification of their feet, demanded by their peculiar life in woods and trees, and are truly organs of support and locomotion. The human foot is also larger, broader, and stronger in proportion to the body, than that of any of the mammalia, and shows that it was designed to support him in an erect posture. The form of the face, and the position of the various organs of the senses in it, prove the same design. Man also is the only animal without any natural clothing or weapons of defence, and is alone left to supply these by his own ingenuity. He is also the only one that prepares his food by fire before using it. In bodily strength, swiftness, and agility, man is inferior to many of the other animals; but his mental endowments enable him to subdue them all, and to render many of them subservient to his uses and enjoyments. It is his intellectual powers, however—the possession of reason and language; of a capacity of continued progressive advancement in science, art, and civilisation; of a moral nature, rendering him a law unto himself, and setting him free from the bond of appetite and passion; and of religion, a knowledge of his relation and duties to the Creator and Supreme Ruler of the universe—that constitute the true distinction of man, and place him at an immeasurable distance above the brute creation.

The influence of climate, civilisation, modes of life, and varieties of food, with the natural tendency to an hereditary transmission of the peculiarities thus produced, appear to be the causes of the numerous varieties of the human race, which seems to have descended originally from one pair, and to form only one species. Every nation, and even family, has some particular features, distinguishing them from others; but there are also differences of a more striking nature. It is usual to divide mankind into the five following varieties:—The Caucasian, or European family of nations, with a white skin, large expanded forehead, soft and copious hair of various colours, and regular features, includes most of the inhabitants of Europe and Western Asia—the Georgians, Circassians, Turks, Jews, Arabs, Persians, and higher castes of the Hindoos. The Mongolian

Fig. 102.

Hindoo.

Fig. 103.

Mongol.

race has a square head, low narrow forehead, thick lips, black eyes placed very obliquely, a yellow or olive colour, and straight strong thin black hair. To it belong the natives of Northern and Central Asia, as the Chinese, Burmese, Calmucks, and Mongols, with the Laplanders, Finns, and probably the Hungarians, in Europe. The African, or Negro variety, have their head narrow and compressed, their forehead low and convex, and the mouth and lower part of the face projecting. Their colour is black, and their hair short and woolly. It includes all the natives of Africa, except some of the Northern States; and the Papuas of Australasia closely resemble them. The American variety have a swarthy copper colour, dark straight hair, a low forehead, with deep sunk eyes. It includes all the native tribes of America, among whom, however, considerable diversity, both in form and mental qualities, exist. The last variety is the

Fig. 104.

Negro.

Fig. 105.

American.

Malay, of a brown colour, with thick black curled hair, their head narrow, their forehead arched, and their features more marked and prominent than in the Negro. They inhabit the Asiatic Islands, and those dispersed over the Pacific Ocean, but, as might be expected, are more diversified in form, colour, and habits, than any of the other varieties.

CONCLUSION.

The account of the nature and objects of the various branches of physical and natural science contained in the preceding pages, will show the importance and utility of these studies. Making known to man the laws which regulate the motions of the heavenly bodies, and the varying phenomena of the globe which he inhabits, they at the same time explain the structure of the various instruments he employs in his daily occupations, the nature of those materials he is constantly making use of, and the properties of the innumerable objects that surround him. There is no class of men who may not derive advantage from this kind of knowledge, whatever be their occupations or pursuits. But, setting aside all other advantages, the intellectual pleasure to be derived from scientific studies, and the knowledge they impart, would be a sufficient inducement to engage in them. No more ennobling or exalted object can be presented to the contemplation of the human mind than the science of Astronomy, which, by means of a few simple laws, explains all the phenomena of the heavens, enables us to foresee them long before they occur, and points out their connexion with facts that are every day observed on the earth. Optics, again, tracing the progress and measuring the velocity of a ray

of light, or resolving it into its primary elements, is no less fitted to arrest attention. The phenomena of Heat, Magnetism, and Electricity—the singular changes which they produce in solid and fluid bodies, with the inquiries into the nature and connexion of these subtle agents—are also extremely interesting. Then how much enjoyment is to be derived from an acquaintance with the various species of the Mineral, the Vegetable, and the Animal Kingdoms! Without this nature is in a great measure a deserted waste, and even the most beautiful scenery affords but a passing gratification. Above all, the human mind is essentially active; its various powers can never rest, and unless employed in some useful or at least innocent pursuit, impel us to vice and dissipation. Science, therefore, by providing an occupation not merely innocent but beneficial, and possessed of a great and enduring interest, is calculated in the highest degree to promote the moral welfare of mankind.

"The highest of all our gratifications in the contemplations of science remains: we are raised by them to an understanding of the infinite wisdom and goodness which the Creator has displayed in his works. Not a step can we take in any direction without perceiving the most extraordinary traces of design; and the skill every where conspicuous is calculated, in so vast a proportion of instances, to promote the happiness of living creatures, and especially of our own kind, that we can feel no hesitation in concluding that, if we knew the whole scheme of Providence, every part would be found in harmony with a plan of absolute benevolence. Independently, however, of this most consoling inference, the delight is inexpressible of being able to follow, as it were, with our eyes the marvellous works of the Great Architect of Nature—to trace the unbounded power and exquisite skill which are exhibited in the most minute as well as the mightiest parts of his system.

"The pleasure derived from this study is increasing, and so various that it never tires the appetite. But it is unlike the low gratifications of sense in another respect: while those hurt the health, debase the understanding, and corrupt the feelings, this elevates and refines our nature, teaching us to look upon all earthly objects as insignificant and below our notice, except the pursuit of knowledge and the cultivation of virtue; and giving a dignity and importance to the enjoyment of life, which the frivolous and the grovelling cannot even comprehend."

THE END.

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